THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

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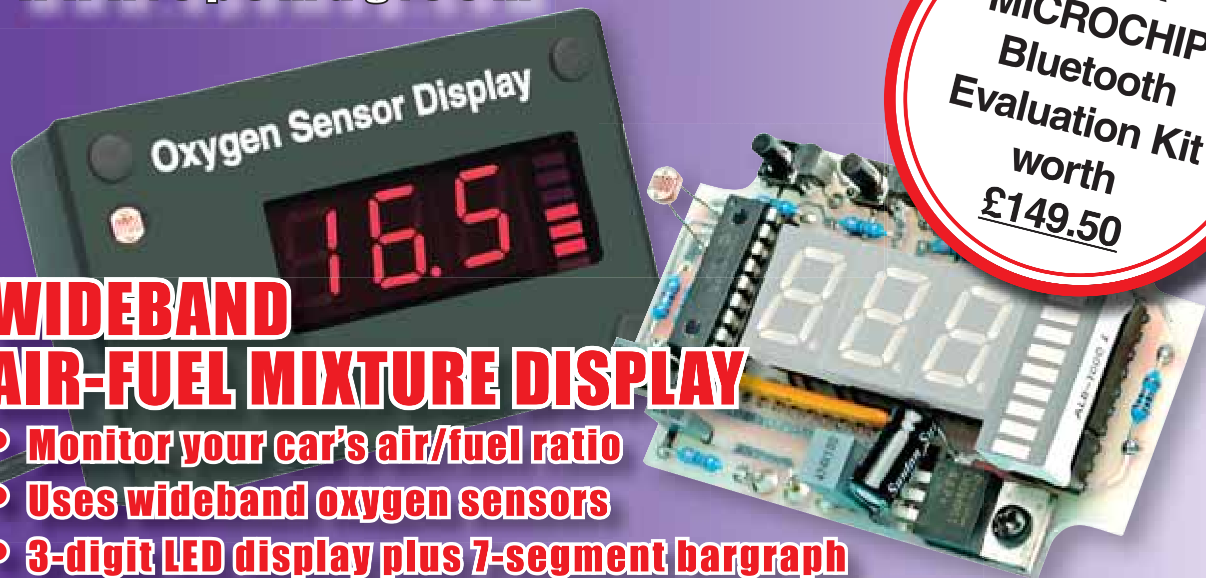
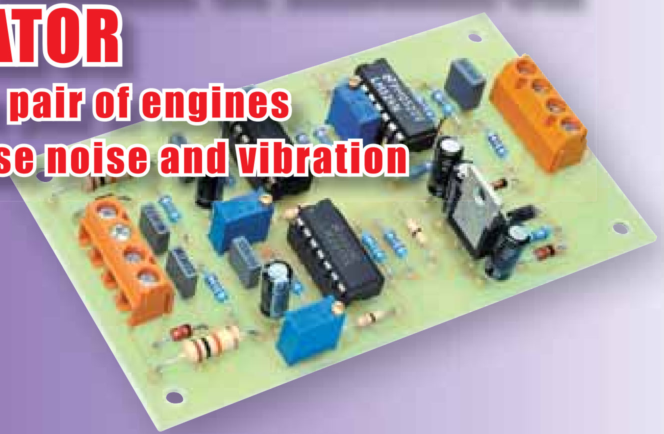


WIDEBAND AIR-FUEL MIXTURE DISPLAY

- Monitor your car's air/fuel ratio
- Uses wideband oxygen sensors
- 3-digit LED display plus 7-segment bargraph
- Can be used to monitor other engine sensor types

TWIN ENGINE SPEEDMATCH INDICATOR

Balance a pair of engines to minimise noise and vibration



UNIVERSAL ANALOGUE AND DIGITAL I/O SOLUTION

A USB, multiplatform project based on the Atmel Atmega32 microprocessor

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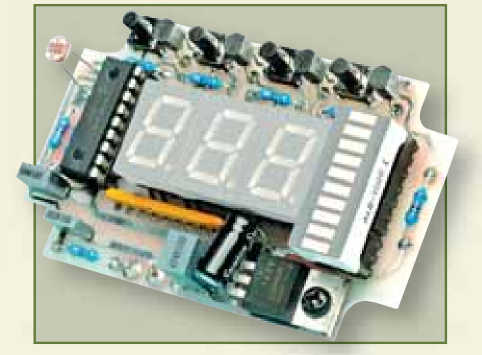

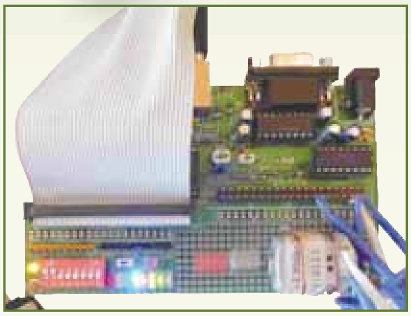

Projects and Circuits

Series and Features

Regulars and Services

Our November 2011 issue will be published on Thursday 13 October 2011, see page 72 for details.

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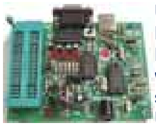
PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £14.95
18Vdc Power supply (PSU121) £24.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer



USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
Kit Order Code: 3149EKT - **£49.95**
Assembled Order Code: AS3149E - **£59.95**
Assembled with ZIF socket Order Code: AS3149EZIF - **£74.95**

USB Flash/OTP PIC Programmer

USB PIC programmer for a wide range of Flash & OTP devices—see website for details. Free Windows Software. ZIF Socket and USB lead not included. Supply: 16-18Vdc.
Assembled Order Code: AS3150 - **£49.95**
Assembled with ZIF socket Order Code: AS3150ZIF - **£64.95**

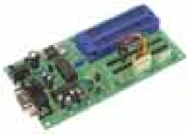
ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
Kit Order Code: 3123KT - **£28.95**
Assembled Order Code: AS3123 - **£39.95**

Introduction to PIC Programming

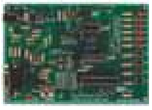
Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual, Programming Hardware (with LED test section), Win 3.11—XP Programming Software (Program, Read, Verify & Erase), and 1rewritable PIC16F84A that you can use with different code (4 detailed examples provided for you to learn from). PC parallel port.
Kit Order Code: 3081KT - **£16.95**
Assembled Order Code: AS3081 - **£24.95**

PIC Programmer Board



Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Requires PC serial port. Windows interface supplied.
Kit Order Code: K8076KT - **£39.95**

PIC Programmer & Experimenter Board



The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
Kit Order Code: K8048KT - **£39.95**
Assembled Order Code: VM111 - **£59.95**

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code PSU303 £9.95

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
Kit Order Code: K8055KT - **£39.95**
Assembled Order Code: VM110 - **£64.95**

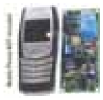
Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12Vdc/6mA (standby). Two *& Ten Channel versions also available.*
Kit Order Code: 3180KT - **£54.95**
Assembled Order Code: AS3180 - **£64.95**

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
Kit Order Code: 3145KT - **£24.95**
Assembled Order Code: AS3145 - **£31.95**
Additional DS1820 Sensors - **£4.95 each**

Remote Control Via GSM Mobile Phone



Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location with GSM coverage.
Kit Order Code: MK160KT - **£14.95**

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
Kit Order Code: 3140KT - **£79.95**
Assembled Order Code: AS3140 - **£94.95**

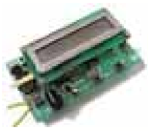
8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
Kit Order Code: 3108KT - **£74.95**
Assembled Order Code: AS3108 - **£89.95**

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
Kit Order Code: 3142KT - **£64.95**
Assembled Order Code: AS3142 - **£74.95**

Audio DTMF Decoder and Display



Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU303). Main PCB: 55x95mm.
Kit Order Code: 3153KT - **£37.95**
Assembled Order Code: AS3153 - **£49.95**

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone operation and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 3191KT - **£27.95**
Assembled Order Code: AS3191 - **£37.95**

CELEBRATING 30 YEARS OF SERVICE

Everyday Practical Electronics FEATURED KITS OCTOBER 2011

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested Down Under. All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

Automotive Kits

Programmable High Energy Ignition Kit

KC-5442 £34.50 plus postage & packing

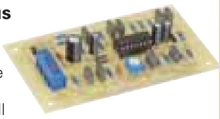
This advanced and versatile ignition system is suited for both two & four stroke engines. Used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing (available separately).

- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment
- Kit includes PCB with overlay, programmed micro, all electronic components and die cast box

Also available to suit:
Ignition Coil Driver Kit KC-5443 £17.25
Featured in EPE November 2009

Knock Sensor

KC-5444 £7.00 plus postage & packing

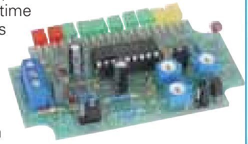


Add this option to your KC-5442 programmable high energy ignition system and the unit will automatically retard the ignition timing if knocking is detected. Ideal for high performance cars running high octane fuel. Requires a knock sensor which is cheaply available from most wreckers. Kit includes PCB with overlay and all specified components.
Featured in EPE November 2009

Voltage Monitor Kit for Cars

KC-5424 £8.50 plus postage & packing

This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.



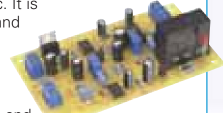
- PCB: 74 x 47mm
- 12VDC
- Recommended box: UB5 use HB-6015 £1.25

Featured in EPE September 2010

Throttle Timer Kit for Cars

KC-5373 £9.25 plus postage & packing

This brilliant design will trigger a relay when the accelerator is pressed or lifted quickly. Used for automatic transmission switching of economy to power modes or trigger electronic blow-off valves on quick throttle lifts etc. It is completely adjustable, and uses the output of a standard throttle position sensor.



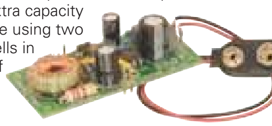
- Kit supplied with PCB, and all electronic components

Featured in EPE November 2006

3V to 9V DC to DC Converter Kit

KC-5391 £6.00 plus postage & packing

This great little converter allows you to use regular Ni-Cd or Ni-MH 1.2V cells, or Alkaline 1.5V cells for 9V applications. Using low cost, high capacity rechargeable cells, the kit will pay for itself in no-time! You can use any 1.2-1.5V cells you desire. Imagine the extra capacity you would have using two 9000mAh D cells in replacement of a low capacity 9V cell.



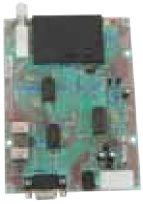
- Kit supplied with PCB, and all electronic components.

Featured in EPE June 2007

Full Function Smart Card Reader / Programmer Kit

KC-5361 £20.00 plus postage & packing

This full function programmer allows you to program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. It hooks up to the serial port of your PC and can be operated as a free-standing unit or installed in a PC drive bay. Cards used need to conform to ISO-7816 standards, which includes ones sold by Jaycar. Powered by 9V via a 9 - 12VDC plugpack or 9V battery.



- Instructions included
- Kit supplied with PCB, wafer card socket and all electronic components.
- PCB measures: 141 x 102mm

Jaycar Electronics and Silicon Chip Magazine will not accept responsibility for the operation of this device, its related software, or its potential to be used for unlawful purposes.
Featured in EPE May 2006

Luxeon Star LED Driver Kit

KC-5389 £11.00 plus postage & packing

Luxeon high power LEDs are some of the brightest LEDs available in the world. They offer up to 120 lumens per unit, and will last up to 100,000 hours! This kit allows you to power the 1W, 3W, and 5W Luxeon Star LEDs from 12VDC. Use super-bright and energy efficient LEDs in your car, boat, or caravan.

- Kit supplied with PCB, and all electronic components.

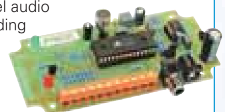
CREE® LEDs also available:
1W White ZD-0424 £6.25
3W White ZD-0442 £9.75
Featured in EPE April 2007

MORE INFO AVAILABLE ONLINE

45 Second Voice Recorder Module

KC-5454 £16.00 plus postage & packing

This kit can record two, four or eight different messages for random-access playback or a single message for 'tape mode' playback. It provides clean and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9-14VDC.



- Supplied with silk screened and solder masked PCB and all electronic components
- PCB: 120 x 58mm

Featured in EPE February 2011

AV Booster Kit

KC-5350 £36.25 plus postage & packing

This kit will boost your video and audio signals preserving them for the highest quality transmission to your projector or large screen TV. It boosts composite, S-Video, and stereo audio signals. Kit includes case, PCB, silkscreened punched panels and all electronic components.

- 9VAC @ 150mA required - use our plugpack MP-3027 £9.00

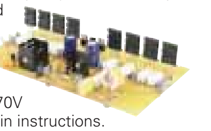
Featured in EPE March 2006

Audio Kits

Studio 350 - High Power Amplifier

KC-5372 £63.50 plus postage & packing

The studio 350 power amplifier will deliver a whopping 350WRMS into 4 ohms or 200WRMS into 8 ohms. It offers real grunt using a high power MJ21193/4 transistor and is super quiet with a very low signal to noise ratio and harmonic distortion. This kit is supplied in short form with PCB and electronic components. Kit requires heatsink and (+/-) 70V power supply as described in instructions. See website for more specifications.

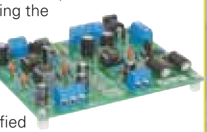


Featured in EPE November 2006

Balanced to Unbalanced Audio Converter

KC-5468 £12.00 plus postage & packing

This kit will adapt an unbalanced input to balanced output and vice versa and allows domestic equipment to be integrated into a professional installation while maintaining the inherent high immunity to noise pick-up on long cable runs provided by balanced lines. Kit supplied with solder masked PCB and all specified components.

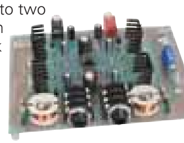


Featured in EPE September 2010

Stereo Headphone Distribution Amplifier

KC-5417 £12.75 plus postage & packing

Enables you to drive up to two stereo headphones from any line level (1volt peak to peak) input. The circuit features a facility to drive headphones with impedances from about 8-600 ohms. The Jaycar kit comes with all specified board components and quality fibreglass tinned PCB.



- Power Supply to Suit: KC-5418 £7.50
- PC board size: 134 x 103mm

Featured in EPE November 2009

Jaycar Electronics

Freecall order: 0800 032 7241

Number One Kits for Electronic Enthusiasts

KIT OF THE MONTH

Wideband Fuel Mixture Controller Kit

KC-5486 £29.00 plus postage & packing

Wideband Fuel Mixture Controller Kit Partner to the Fuel/Air Mixture Display Kit KC-5485 (see below) and intended to be used with a Bosch wideband LSU4.2 oxygen sensor to accurately measure air/fuel ratios over a wide range from rich to lean. It can be used for precise engine tuning and can be a permanent installation in the car or a temporary connection to the exhaust tailpipe. Requires Bosch Wideband oxygen sensor LSU4.2.

- 12VDC
- PCB and electronic components
- Programmed PIC
- Case with screen printed lid

Speedo Corrector MkII Kit for Cars

KC-5435 £20.00 plus postage & packing

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. With this improved model, the input setup selection can be automatically selected and it also features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components.

- PCB: 105 x 61mm

12/24VDC 20A Motor Speed Controller Kit

KC-5502 £14.50 plus postage & packing

Control the speed of 12 or 24VDC motors from zero to full power, up to 20A. Features optional soft start, adjustable pulse frequency to reduce motor noise, and low battery protection. The speed is set using the onboard trimpot, or by using an external potentiometer (available separately, use RP-3510 £1.00).

NEW 2011

- Kit supplied with PCB and all onboard electronic components
- Suitable enclosure UB3 case, HB-6013 £1.50

Fuel/Air Mixture Display Kit

KC-5485 £21.75 plus postage & packing

Display your car's air-fuel ratio as you drive. Designed to monitor a wideband oxygen sensor and its associated wideband controller but could be used to monitor a narrowband oxygen sensor instead. Alternatively, it can be used for monitoring other types of engine sensors.

- Double-sided plated through PCB
- Programmed PIC
- Electronic components
- Case with machined and screen printed lid
- PCB: 80 x 50mm

IR Remote Extender MKII Kit

KC-5432 £10.00 plus postage & packing

Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. This improved model features fast data transfer, capable of transmitting PayTV digital remote control signals using the Pace 400 series decoder. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

- PCB: 79 x 47mm
- Requires 9VDC wall adaptor

Clifford The Cricket

KC-5178 £6.25 plus postage & packing

Clifford hides in the dark and chirps annoyingly until a light is turned on - just like a real cricket. Clifford is created on a small PCB, measuring just 40 x 35mm and has cute little LED insect eyes that flash as it sings. Just like a real cricket, it waits a few seconds after darkness until it begins chirping, and stops instantly when a light comes back on.

- PCB, piezo buzzer, LDR plus all electronic components supplied

Hundreds Sold

Universal Power Supply Regulator

KC-5501 £5.50 plus postage & packing

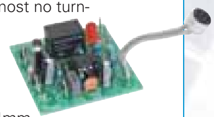
This is an upgraded version of the original universal power supply kit published in August 1988. One small board and a handful of parts will allow you to create either a regulated ±15V rail or +15VDC single voltage from a single winding or centre tap transformer (not included).

- Includes all PCB and components for board, transformer not included
- PCB: 72(L) x 30(W)mm

"Minivox" Voice Operated Relay

KC-5172 £6.00 plus postage & packing

Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces and has almost no turn-on delay. 12VDC @ 35mA required. Kit is supplied with PCB electret mic, and all specified components.

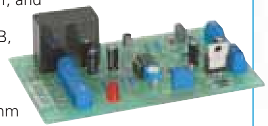


- PCB Dimensions: 47 x 44mm

Universal Voltage Switch

KC-5377 £12.00 plus postage & packing

This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. You could even use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and all electronic components.



- PCB: 105 x 60mm

ULTRASONIC WATER TANK LEVEL INDICATOR KIT

KC-5503 £27.25 plus postage & packing

Designed for plastic and concrete tanks, or steel tanks with modification, this water level indicator kit uses an ultrasonic assembly that mounts inside the tank and a microprocessor controlled meter to display the water level. Selectable between 10 LED Bargraph or 19 level Dot mode. Easy to calibrate, can be pushbutton or permanent display, powered by a 9V battery or power adaptor (available separately) and can be used with fluids other than water. Kit includes PCB, waterproof case and all electronic components. Silicon sealant not included.

- Suits tanks up to 2.4m high
- PCB: 104 x 78.5mm

NEW 2011

MORE INFO AVAILABLE ONLINE

Don't just sit there BUILD SOMETHING!

Ultrasonic Antifouling for Boats

KC-5498 £90.50 plus postage & packing

Marine growth electronic antifouling systems can cost thousands. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in sturdy polyurethane housings. By building yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. The single transducer design of this kit is suitable for boats up to 10m (32ft); boats longer than about 14m will need two transducers and drivers. Basically all parts supplied in the project kit including wiring. (Price includes epoxies).

MORE INFO AVAILABLE ONLINE

- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB: 78 x 104mm

Post & Packing Charges

Order Value	Cost
£10 - £49.99	£5
£50 - £99.99	£10
£100 - £199.99	£20
£200 - £499.99	£30
£500+	£40
Max weight 12lb (5kg)	
Heavier parcels POA	
Minimum order £10	

Note: Products are despatched from Australia, so local customs duty & taxes may apply.

- **All pricing in Pounds Sterling**
- **Minimum order £10**

Prices valid until 31/10/2011

HOW TO ORDER

WEB:	www.jaycarelectronics.co.uk
PHONE:	0800 032 7241*
FAX:	+61 2 8832 3118*
EMAIL:	techstore@jaycarelectronics.co.uk
POST:	P.O. Box 107, Rydalmere NSW 2116 Australia

*Australian Eastern Standard Time (Monday - Friday 09.00 to 17.30 GMT + 10 hours)

Expect 10-14 days for air parcel delivery

Order online: www.jaycarelectronics.co.uk

Jaycar Electronics

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Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: (01202) 880299. **Fax:** (01202) 843233.
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Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

Editor: MATT PULZER
Consulting Editor: DAVID BARRINGTON
Subscriptions: MARILYN GOLDBERG
General Manager: FAY KEARN
Graphic Design: RYAN HAWKINS
Editorial/Admin: (01202) 880299
Advertising and Business Manager: STEWART KEARN (01202) 880299
On-line Editor: ALAN WINSTANLEY
EPE Online (Internet version) **Editors:** CLIVE (Max) MAXFIELD and ALVIN BROWN
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EVERYDAY PRACTICAL ELECTRONICS

A toast to ingenuity

In what little spare time I have, I do an Open University (OU) degree in mathematics. It's interesting and nicely complements my original degree in engineering. Part of my current course involved a week-long summer school at the University of Nottingham, where OU students got a taste of 'conventional' university life and the chance to study in depth without the usual distractions of day-to-day life.

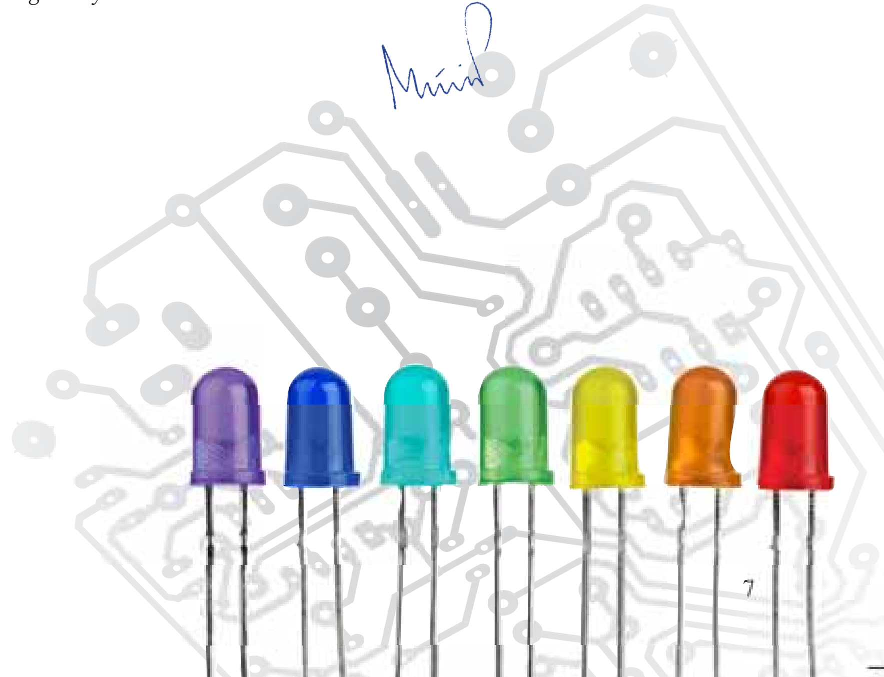
One of the best aspects of this week was the wonderfully diverse collection of people who attended; from HM Treasury officials to Polish waitresses, and 18-year olds to 80-year olds, there was a great cross-section of people who all share a passion for 'doing sums'.

One of the most interesting people I met was Alan Kerslake, an engineer from Rosyth. He had trained in the navy as an apprentice (in electronics) and remembered *EPE* in it's former incarnation as *Practical Electronics* (*PE*). Alan had many fascinating stories of navy life, but the one that stuck in my memory was a great tale of British 'make do and mend' from when he was in the South Atlantic during the Falklands campaign.

One of the radar units on his ship developed a serious fault, which was traced to a large high-current inductor. He radioed round the fleet, but no spare could be found. This was clearly neither the time nor the place for a warship to be 'blind', so a fix had to be found, and found quickly.

Alan went down to the ships stores for a good rummage, where he spotted some large catering toasters for the galley. Out came the coiled elements, and with the help of a rheostat, meter and function generator he determined that the coils had the current carrying capacity of the failed inductor and a third of its inductance. So, with a bit of ingenuity the radar was fixed with three toasters (British, of course). I say fixed, but upgraded might be a better description, since it's range was increased from 80 to 115 miles. Alan, a modest man, who told this story for its amusement value and not to blow his own trumpet, did admit that his captain had been 'quite impressed'.

A great tale of a *PE*-reading engineer, who had the imagination to see through the system complexity and fix a serious problem with the most humble of components. Alan certainly gets my retrospective vote for '*Ingenuity Unlimited*' winner of 1982.



NEWS

A roundup of the latest Everyday News from the world of electronics

EPE's Barry Fox challenges LG Electronics' 3D TV ad **by Barry Fox**

The Advertising Standards Authority (ASA), which aims to keep adverts 'Legal, decent, honest and truthful', is formally considering a complaint lodged by a competitor of LG Electronics, over full-page magazine adverts for passive 3D TV, placed by LG in early July.

I can report this because I lodged a consumer complaint after LG's appointed press officers repeatedly failed to offer requested press comment on the adverts – on one occasion promising action 'tomorrow' and then failing to follow through.

LG's adverts were headed 'It's 3D TV (but not as we know it)' and promoted 'the world's first flicker free TV with HD 1080p enhanced picture quality giving you a screen that's clearer and twice as bright as conventional 3D TVs… with ultra wide viewing so more of your family and friends can get in on the action.'

The adverts went on to explain that 'ultra-wide viewing means you can sit where you want… unlike other 3D TVs, with LG Cinema 3D everyone will feel the full effect of the 3D experience… because the ultra-wide viewing angles allow you and your family and friends to sit where you want in comfort.'

The ASA says that 'in relation to points regarding the advertiser's claims about passive '3D ultra wide viewing' and 'the world's first flicker free TV', we have recently received a competitor complaint and… that complaint is currently under investigation.'

Although passive 3D screens may have a wide horizontal viewing angle, the horizontal strips of polarising material over the screen considerably restrict the vertical viewing angle; the strips also reduce the picture brightness in 2D mode.

However, the ASA says that the competitor has not complained about 'the advertiser's claim that their TV is 'clearer and twice as bright… as conventional 3D televisions' so 'being a specialist competitor we would therefore think it likely that this is not a problematic claim (and) unlikely to materially mislead people to their detriment.'

It is unclear why LG's competitor did not complain on these counts. The 'twice as bright' claim is mathematically specific, while failing to offer any quantifying/qualifying explanation or evidence or reference point.

The ASA would surely investigate if a carmaker broadly claimed a car that was 'twice as fast'!

LG's main competitors in the UK are Panasonic, Sony and Samsung, all selling active shutter 3D TVs. A spokeswoman for Panasonic UK says 'As far as I know we have not lodged a complaint'. Samsung's press team says ambiguously 'sorry this is not something we know anything about'. Sony has so far failed to respond usefully.

Pico Technology launches new three-channel mains current data logger

The new PicoLog CM3 USB/Ethernet current data logger is a compact, easy-to-use instrument for measuring power consumption. With three channels, it can monitor current in single-phase and three-phase AC installations. Applications include monitoring three-phase motors and generators, measuring the consumption of heating, ventilation and air conditioning (HVAC) systems, and balancing phases in multiphase supplies. The logger is supplied complete with three AC current clamps and a powerful data acquisition software package.

The PicoLog CM3's measuring range is 0 to 200A, with an accuracy of ±1% and less than 10mA of noise. The conversion resolution is 24 bits. It is supplied with 'PicoLog' data logging software, which runs on any PC with Windows XP or later. PicoLog can collect data from up to 20 PicoLog CM3s at programmable intervals from 720ms per channel up to minutes, hours or even days.

It displays readings in a monitor window with optional limit alarms, alongside optional live graph and table views of the same data. You can export readings in a standard text format compatible with other spreadsheet and analysis programs.

Priced at £349, the PicoLog CM3 is covered by Pico's free five-year parts-and-labour warranty and free technical support. More information can be found at: **www.picotech.com**

Pico Technology's new current data logger works with single- and three-phase systems

Microchip announces new analogue resistive USB touch-screen controller

The AR1100 controller is a high-performance, USB plug-and-play device that builds on the AR1000 analogue resistive touch-screen controller series and offers advanced calibration capabilities as a USB mouse or single-input digitiser. The new controller is available as a turnkey chip or board product, supporting all 4-, 5- and 8-wire touch screens, with free drivers for most major operating systems.

The mTouch AR1100 Development Kit (DV102012), priced at $89.99, includes an AR1100 production-ready PCB, with a USB cable and a 5-wire analogue-resistive touch screen, enabling designers to quickly connect and test this advanced touch-screen controller. For further information, visit Microchip's Website at: **www.microchip.com/get/08XT**

Microchip has launched the AR1100 IC to work with touch screens

The Libstock community – Facebook for coders!

Libstock is a community website created by mikroElektronika, which allows users to share their projects. It lets you stay in touch with fellow contributors, to be notified of code changes, discuss code implementation, and express your wishes for new development.

Libstock allows sharing of three major code types: libraries, projects and visual TFT/GLCD projects. Within those types, you can share whatever is necessary, or whatever you find suitable and helpful to the end user. If you want to share your library, you can also provide examples, connection schematics, help files, datasheets, additional documentation, and even PCB designs.

But Libstock is much more than that. It's like Facebook for coders! See Libstock at: ***www.libstock.com***

Brits Bing more then they Yahoo!

Google may be the search engine of choice for most of us, but Microsoft's foray into this all-important feature of the Internet has started to pay dividends – in Britain at least. The software giant's 'Bing' search engine accounted for 3.84% of all UK searches in July, overtaking Yahoo! with 3%. That made Bing the number two search engine in Britain.

Brainy chips

IBM has unveiled a new generation of experimental computer chips designed to emulate the brain's abilities for perception, action and cognition. IBM hopes the technology may yield many orders of magnitude less power consumption and space than used in today's computers.

In a sharp departure from traditional concepts in designing and building computers, IBM's first neurosynaptic computing chips recreate the phenomena between spiking neurons and synapses in biological systems, such as the brain, through advanced algorithms and silicon circuitry. Called 'cognitive computers', systems built with these chips won't be programmed the same way traditional computers are today. Rather, cognitive computers are expected to learn through experiences, find correlations, create hypotheses, and remember – and learn from – the outcomes, mimicking the brains structural and synaptic plasticity.

IBM has two working prototypes. Both cores were fabricated in 45nm SOI-CMOS and contain 256 neurons. One core contains 262,144 programmable synapses and the other contains 65,536 learning synapses. The IBM team has demonstrated simple applications like navigation, machine vision, pattern recognition, associative memory and classification.

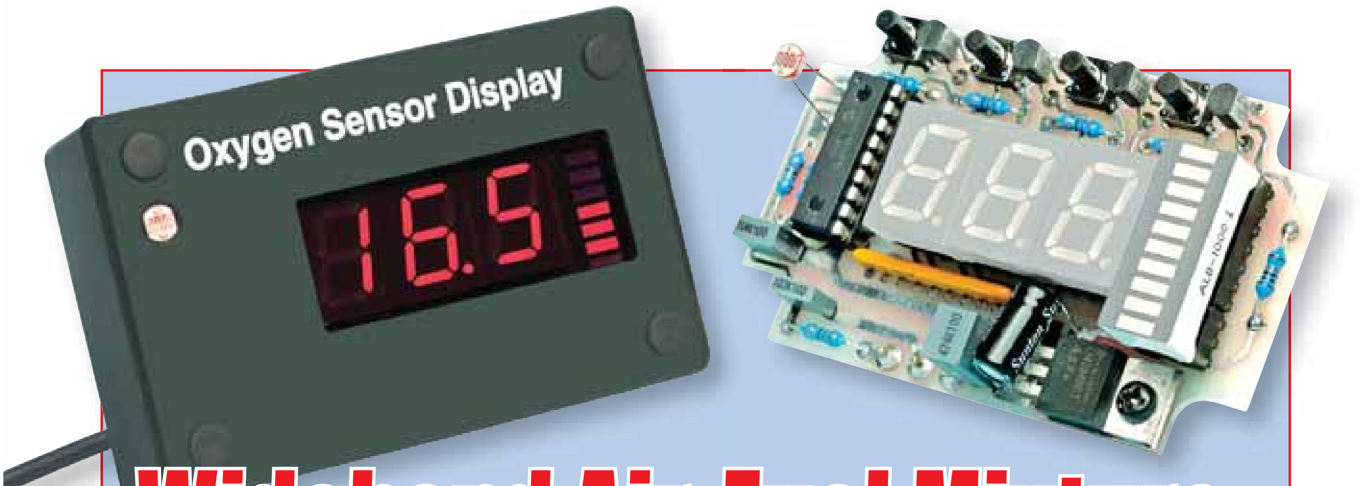
Brunning launches PICs and power course

Brunning Software has announced the imminent release of their new training course for 16F and 18F XLP PIC microcontrollers. The 'PICs and Power' training course will be ready for sale at the end of September. Unlike their current PIC training courses, this latest course expects the student to have some electronics and programming experience and to know a little about PIC microcontrollers. A new 340-page book Experimenting with PICs and Power *starts easily enough for complete beginners, but rapidly gathers pace. A multi-purpose circuit is also being offered to go with the course, although there are details in each section of the book to enable the reader to build their own circuits. The circuit has sockets for all the usual PIC sizes, and sockets for a 16-character by two-line display, keypad, audio output, thermistor, and experimental USB. It also has eight high-current MOSFETs onboard, arranged as two P+N bridges. These tiny surface-mount MOSFETs have a maximum on resistance of a mere 0.012Ω, a continuous current rating of 12A, and a peak rating of 96A. The full circuit is conservatively rated to drive up to 16V at 5A for motors or stepper motors.*

A multi-purpose circuit is offered with Brunning's 'PICs and Power' course

The book is packed with detailed study material from flashing LEDs to high torque DC motor speed control and stepper motor control. The last chapter covers micro stepping techniques from first principles. The circuit board has sockets for connecting either a PICkit3 or a Brunning Software programmer for writing the code into the PIC. A software library on CD is also provided, along with a USB-to-USART adaptor, which is needed for the motor control serial experiments between PC and PIC.

The course will initially be available only as fully built and ready to go. A low-cost version requiring assembly is planned for 2012. For more details, see: ***www.brunning-software.co.uk/pap.htm****; tel:* ***Brunning Software +44 (0)1255 862308****.*



Wideband Air-Fuel Mixture Display

By JOHN CLARKE

Monitor your car's air/fuel ratio as you drive

This Wideband Oxygen Sensor Display can show your car's air/fuel ratio as you drive. It's designed to monitor a wideband oxygen sensor and its associated wideband controller, but could be used to monitor a narrowband oxygen sensor instead. Alternatively, it can be used for monitoring other types of engine sensors.

WHY would you want to monitor the air/fuel ratio as you drive? Well, for starters, it will allow you to save fuel, since the display clearly indicates when the engine is running rich.

When used in conjunction with a wideband oxygen sensor and controller, the air/fuel ratios shown on this unit are more accurate than can be obtained from the narrowband sensors that are typically used in cars and which are really only accurate close to the 'stoichiometric' point (ie, the air/fuel ratio at which there is just enough oxygen in the air to ensure complete combustion).

Under normal driving, most engine management systems operate under 'closed-loop' control. This is where the air/fuel ratio from an oxygen sensor is monitored and controlled by the car's engine control unit (ECU) to maintain a predetermined fuel mixture. This is usually stoichiometric, but under light cruise conditions the mixture can go lean to improve fuel economy.

Conversely, during acceleration, the air/fuel mixture in many cars is allowed to go rich to improve performance and is not under the control of the ECU. This is called 'open-loop' and the richness of the mixture depends on other factors, such as the throttle setting and the injector opening period.

Economy drive

By monitoring the air/fuel mixture display as you drive, you will quickly learn how to obtain the best economy. When climbing a hill, for example, the car would normally be running rich, so you can ease off on the throttle just enough to return the ECU to closed-loop control and run at stoichiometric mixtures to reduce the amount of fuel used.

In addition, when gear changes are required, you may find that changing earlier or later than normal will keep the engine running leaner for longer.

Similarly, when travelling downhill without throttle, most cars shut off the injectors above a certain RPM limit, so that no fuel is used at all. When this happens, the display will show a very lean air/fuel ratio.

Note, however, that the injectors are usually partially open below this RPM limit, to ensure a smooth engine response when the throttle is opened. This means that when travelling downhill, it may be better to

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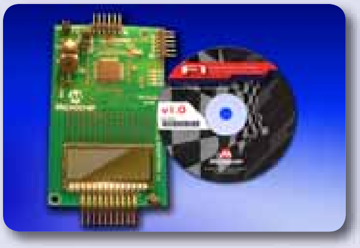

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drop down a gear to ensure complete injector shut-off (and thus reduced fuel usage), rather than stay in a higher gear with the injectors slightly open.

Diagnosing problems

Once you've used this unit for a while, you will soon learn what sort of readings to expect in every-day driving. Any subsequent variations from 'normal' can then be interpreted as indicating a problem. For example, there could be a fault with the oxygen sensor, the wideband controller or the engine management unit. A problem with fuel delivery is another possibility.

Oxygen sensors do wear out eventually, due to an accumulation of contaminants on the sensor tip. As a result, car manufacturers recommend that they be replaced after a specified number of kilometres (typically around 100,000km for a heated sensor type). A worn-out oxygen sensor becomes sluggish in its response and causes a number of problems, including excessive fuel consumption, poor engine performance, accelerated catalytic converter damage and increased emissions.

By monitoring your car's air/fuel ratio as you drive, you can quickly discover abnormal operating conditions and have the sensor checked and, if necessary, replaced.

Engine modifications

This unit will also be invaluable if you are a car modification enthusiast. It will soon show whether or not the mixture is too lean during acceleration or too rich under cruise conditions, and allow you to make adjustments accordingly.

This can be particularly handy if you are swapping the ECU chip for an after-market type, or if you are experimenting with the fuel injectors. It's all too easy to damage an engine if the mixture is too lean under certain circumstances.

Oxygen sensor types

In order to monitor the air/fuel ratio, the vehicle must be fitted with an oxygen sensor. These are fitted to all vehicles that have fuel injection and engine management, although most cars use what is known as a 'narrow-band' oxygen sensor.

In practice, the oxygen sensor is located in the exhaust system to monitor the exhaust gas after the fuel has been burnt in the engine. Basically, the fuel is mixed with air inside each cylinder prior to firing. This air/fuel ratio is varied under the control of the ECU in order to obtain the desired engine (and emissions) performance.

Under light engine-load conditions, the engine is usually run with exactly the correct proportion of fuel and air to ensure complete combustion. When this happens, the air/fuel ratio is said to be 'stoichiometric' and this ratio is typically 14.7 for unleaded petrol. Putting it another way, 14.7kg of air is mixed with each 1kg of the unleaded fuel to achieve the stoichiometric ratio.

Note, however, that the stoichiometric ratio is different for different fuels because it depends on the chemical composition of the fuel and its combustion characteristics. For liquid petroleum gas (LPG), the stoichiometric value is typically 15.5 (ie, 0.8 greater than for unleaded petrol).

Main Features and Specifications

MAIN FEATURES

- 3-digit LED display plus 7-segment bargraph
- Linear display with 0V to 5V wideband range, or 0V to 1V S-curve range
- Alternative display switching (A or B readings for wideband values); petrol or LPG readings for narrowband S-curve
- 0V and 5V endpoint value limit adjustments for both A and B displays
- Decimal point positioning
- Display leading zero suppression
- Bargraph can be operated in dot, bar or centred-bar mode for wideband range. S-curve set-up allows for dot or centred-bar styles
- Display dimming with minimum brightness and dimming threshold adjustments
- Quieting period used for input measurement to ensure accuracy

SPECIFICATIONS

Power supply: 6V to15V @ 240mA (full display brightness)

Input current loading: less than ±1μA

Digit update period: 250ms

Bargraph update period: 30ms

Wideband display reading range: 0-999

Narrowband display reading range: 11.8 to 20.6 for unleaded petrol with the stoichiometric ratio set for 14.7; 12.6 to 21.4 for LPG with stoichiometric at 15.5. The display shows an 'L' for ratios below the lowest value and an 'r' for ratios above the highest value.

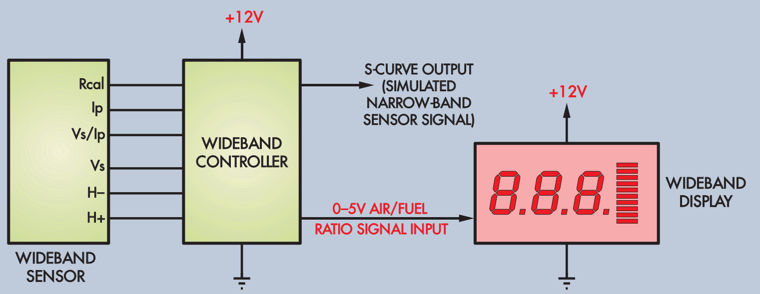


Fig.1: here's how the display unit is used with a wideband sensor and its associated controller. The narrowband S-curve output from the controller is fed to the engine management computer (see text).

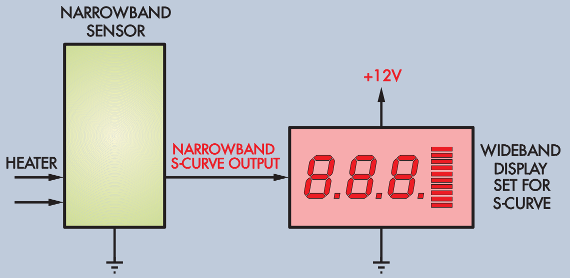


Fig.2: the original narrowband sensor fitted to the car can be used to directly drive the display unit if accuracy isn't important. The display must be set to run in S-curve mode.

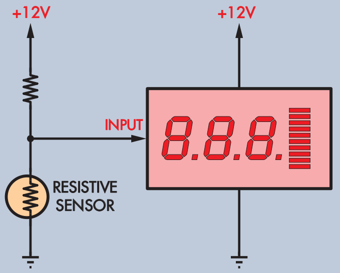


Fig.3: here's how to use the display unit with a resistive sensor (eg, a temperature gauge).

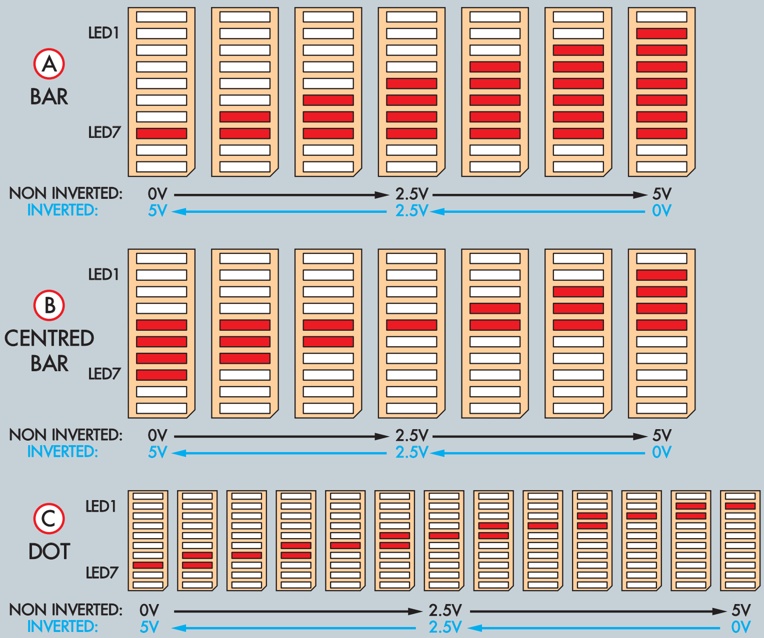


Fig.4: this diagram shows the bargraph display options that are available when the display unit is operating in wideband mode: (a) bar; (b) centred bar; and (c) 13-step dot. In each case, the bargraph can also operate in inverted mode.

During acceleration, the engine is commonly run with a rich mixture, meaning that more fuel is added to the air compared to that used in the stoichiometric ratio. As a result, the air/fuel ratio becomes lower in value. This rich mixture provides more power under load – at the expense of fuel economy.

Unburnt hydrocarbons

When the mixture is rich, there is insufficient oxygen in the air/fuel mixture to provide complete combustion. As a result, unburnt hydrocarbons are present in the exhaust gas.

Conversely, when the engine is running in cruise conditions, the fuel supplied to the engine can be reduced to produce a 'lean' mixture, so that there is residual oxygen in the exhaust. This is done to improve fuel economy and results in an air/fuel ratio that's slightly higher than stoichiometric.

Another way of specifying the air/fuel ratio is to 'normalise' the stoichiometric value, so the ratio is referenced to 1. We call this normalisation the 'lambda' (λ) value and it has a value of '1' at the stoichiometric point.

Basically, the lambda value is simply the actual air/fuel ratio divided by the stoichiometric ratio. This means that lean air/fuel ratios have a lambda greater than 1, while rich air/fuel ratios have a lambda that's less than 1.

In practice, air/fuel ratios are a compromise between driveability, engine power and the production of air pollutants. Air pollutants are also reduced using a catalytic converter. This converts nitrous oxides to nitrogen and oxygen, carbon monoxide (CO) to carbon dioxide (CO_2) and the unburnt hydrocarbons into carbon dioxide and water.

Oxygen sensor display unit

As shown in the photos, the Oxygen Sensor Display unit is housed in a small plastic case. It features a 3-digit LED display to show the air/fuel ratio, plus a 7-segment bargraph, which indicates the signal trend.

Just three leads are used to connect the unit to you car: one for 12V power, another for the ground (0V) and the third for the signal. In addition, two more leads can be wired to switch the unit from one set of display values to another.

Inside the box are four pushbutton switches located along the top edge of the PC board. These are used to initially set up the way the unit works. However, they are not normally used once the various settings have been made.

Another feature of the unit is automatic display brightness. During daylight, the displays are driven to full brightness so that they can be easily seen. By contrast, as the ambient light dims, the display brightness is reduced so that they don't become distracting, particularly at night.

What type of oxygen sensor to use

A wideband oxygen sensor also requires the use of a wideband controller unit, such as this Tech edge WB02 2J1. It provides a 0V to 5V output which is fed to the Oxygen Sensor Display unit, plus a simulated narrowband S-curve output that's fed to the engine management computer.

VIRTUALLY all cars come fitted with narrowband oxygen sensors, and if you want to save money and accuracy isn't important, you can use the existing sensor with the Oxygen Sensor Display. That said, it's best to substitute the Bosch LSM11 narrowband oxygen sensor, since the display unit is calibrated for this sensor in narrowband mode.

Conversely, if you want high accuracy, you must use a wideband oxygen sensor such as the Bosch LSU 4.2. This must be teamed with a wideband controller that gives a 0V to 5V output. Such controllers include the Tech Edge WB02 2J1 (**http://wbo2.com/home/products.htm**) and the Innovate Motosports LC-1 (**http://www.innovatemotorsports.com/products.php**).

As far as we are aware, there are only a few vehicles, such as Audi and VW, that have factory-fitted wideband sensors, so the chances are that you will have to buy a wideband sensor and fit it. In most cases, all you have to do is remove the existing narrowband sensor, substitute the wideband sensor and team it with a wideband controller. The simulated narrowband S-curve output from the wideband controller is then connected to the vehicle's engine management computer. This replaces the signal from the original narrowband sensor and allows the engine to operate normally – see Fig.1.

The 0V to 5V output from the wideband controller unit is connected to the display unit, which then provides accurate air/fuel mixture readings.

Fig.1 shows how the unit is used with a wideband sensor and its associated controller. As can be seen, the 0-5V output from the controller provides the air/fuel ratio signal for the Oxygen Sensor Display. In addition, a wideband controller usually has a simulated S-curve output and this can be used to replace the signal from the original narrowband sensor for the engine management computer.

By using the 0V to 5V signal from the controller, the display unit can be set up to show the air/fuel ratio over a set range. For example, it could be set to show air/fuel ratios between 7.4 and 22.0. These values are set to match the 0V to 5V range from the wideband controller, with the unit responding in a linear fashion.

That's not all it can do though. Basically, this unit can be set to display whatever values you wish. For example, it could be set to show lambda values from say 0.51 to 1.50 instead.

Alternatively, you can set it up to display either the air/fuel ratio or the lambda value at the flick of a switch. In that case, there are two sets of values labelled 'A' and 'B', and you select between them.

Similarly, for cars that run on both unleaded petrol and LPG, it's possible to switch the unit so that it displays the correct air/fuel ratio for the selected fuel.

Narrowband sensor

How the unit is used with a narrowband oxygen sensor is shown in Fig.2. In this case, the display includes a preset response for the standard Bosch LSM11 narrowband oxygen sensor and shows the air/fuel ratio for unleaded petrol from 11.8 to 20.6 (stoichiometric at 14.7).

For air/fuel ratios below 11.8, the display shows an 'r' for rich, while ratios above 20.6 give an 'L' for lean. Similarly, for LPG, the range is 12.6 to 21.4 (stoichiometric at 15.5), with an 'r' shown for ratios below 12.6 and an 'L' for ratios above 21.4.

One option here is to have a dot or a centred bargraph display for the S-curve narrowband mode. For more information on this, refer to the panel titled 'Using the unit with a narrowband sensor'.

If the output from the sensor does not cover the full 0V to 5V range, then the values set at the 0V and 5V end points are obtained by extrapolation. This involves first drawing a graph similar to Fig.9 or Fig.10 that shows two points that correspond to the output from the sensor and their corresponding values. The graph is then extended until it reaches the 0V and 5V points.

The values that are obtained at the 0V and 5V points are the endpoint values that need to be entered into the display during the setting up procedure.

Bargraph display

As indicated previously, the LED bargraph shows the sensor voltage level and is useful for indicating the voltage trend. Its response to voltage changes is significantly faster than that of the digital display, which is deliberately slowed down so that the values can be easily read.

Fig.4 shows the three bargraph display options that are available in the wideband operating mode. Note that

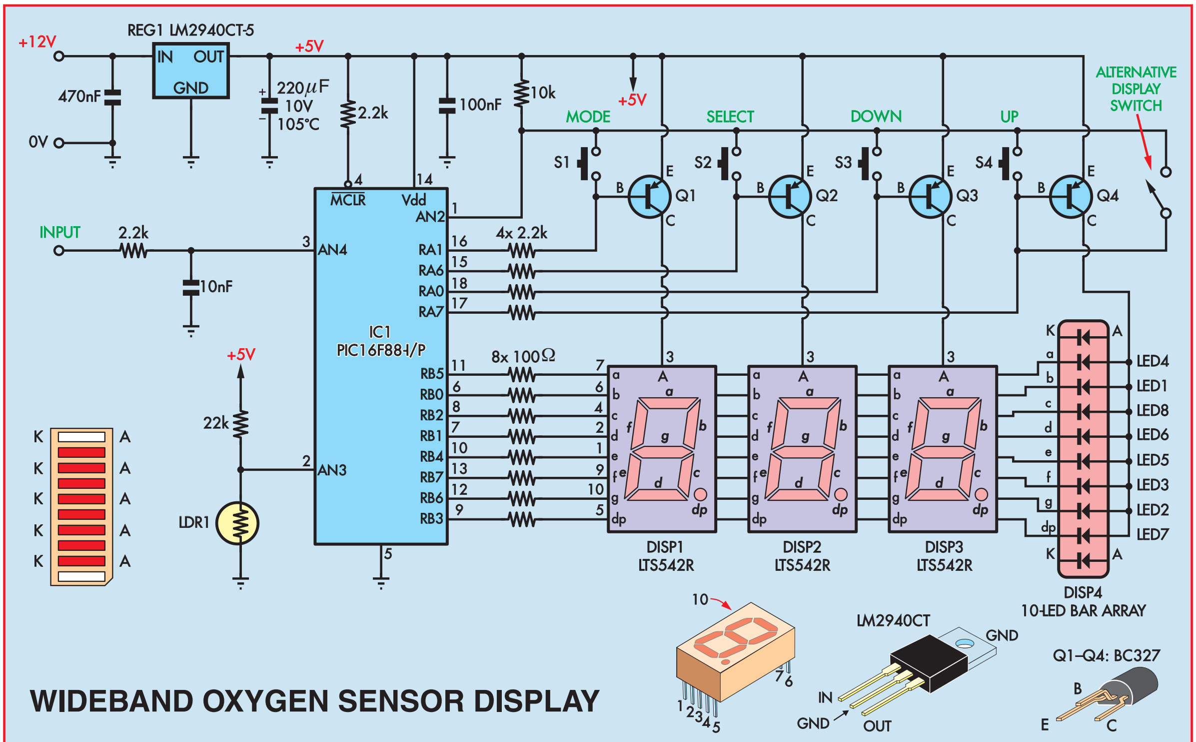


Fig.5: the circuit is based on a PIC16F88-I/P microcontroller (IC1). This processes the sensor signal at its AN4 (pin 3) input and drives three 7-segment LED displays and an 8-LED bargraph in multiplex fashion.

although a 10-LED bargraph display is used, only seven LEDs are used in these displays.

Fig.4(a) shows the 'Bar' display mode. Here, the number of LEDs lit increases from one to seven over six steps in response to a rising sensor voltage. Alternatively, it can be set up to increase the number of LEDs lit in response to a falling sensor voltage (ie, an inverted display).

The 'Centred Bar' mode is displayed in Fig.4(b). In this mode, the centre bar is always lit (2.5V sensor output), with the bar then extending either up or down in response to a rising or falling sensor voltage. Once again, an inverted display option is available.

This option is the most useful when showing the air/fuel ratio, with the bars indicating as the mixture moves into either rich or lean ratios. The centre bar is the stoichiometric point.

Finally, Fig.4(c) shows the 'Dot' mode option. In this case, there are 13 levels, with either one or two LEDs being lit as the sensor voltage varies. As with the previous two modes, an inverted display option is available.

Circuit details

Despite its versatility, the circuit for the Wideband Oxygen Sensor Display is really very simple. Fig.5 shows the details.

As shown, it's based on a PIC16F88-I/P microcontroller (IC1), with most of the clever stuff hidden inside its firmware program. Apart from that, there are the three 7-segment LED displays (DISP1 to DISP4), the 10-LED bargraph display, four driver transistors (Q1 to Q4), a 3-terminal regulator (REG1) and a few sundry bits and pieces.

IC1 monitors the input voltage from the sensor, processes the data and drives the LED displays to show the calculated air/fuel ratio value. Output ports RB0 to RB7 drive the display segment cathodes, while transistors Q1 to Q4 switch the common display anodes, ie, the displays are multiplexed so that only one display digit is driven at any given time.

Note that all the segments common to each display are tied together. For example, the 'a' segment of DISP1 connects to the 'a' segments of DISP2 and DISP3. In addition, LED4 within the LED bargraph (DISP4) also connects to the 'a' segments of DISP1 to DISP3.

These 'a' segments are driven via the RB5 output of IC1 via a 100Ω resistor. As a result, when this output is low, the 'a' segment in one display will light, depending on which driver transistor is turned on.

The *PNP* transistors Q1 to Q4 are driven by ports RA0, RA1, RA6 and RA7 via 2.2kΩ resistors. For example, transistor Q1 is controlled by RA1, and when this output is high, Q1 is held off.

Conversely, when RA1 goes low (0V), Q1's base (B) is pulled low via its 2.2kΩ resistor and so Q1 turns on. As a result, any segments within DISP1 that have their cathodes pulled low via IC1's RB outputs (and their respective 100Ω resistors) will now light.

Transistors Q2, Q3 and Q4 are driven in a similar manner to Q1 to control DISP2, DISP3 and the LED bargraph

Using it as a general-purpose display

BECAUSE it's based on a microcontroller, this unit can also be used as a general-purpose display to monitor other sensors (ie, you don't have to use it with an oxygen sensor).

Basically, it can display any number ranging from 0 to 999 in response to any sensor with a 0V to 5V output signal. You can set it up so that the display either increases in value as the sensor output voltage increases, or set it so that the display decreases in response to rising sensor voltages. A decimal point can also be included and can be positioned after the first or second digit.

If no decimal point is selected, then the display features leading zero blanking. This means that a value of 007, for example, will be displayed as 7, while a value of 021 will be displayed as 21. Similarly, if the decimal point is positioned after the second digit, a value of say 00.2 will be shown as 0.2.

This decimal point selection and zero blanking feature also applies when displaying air/fuel ratios from a wideband controller.

(DISP4). For example, to light DISP2, we switch off Q1, set the required segment driver outputs required for the DISP2 display and then switch on Q2 by taking RA6 low. A similar process is then used to switch on DISP3 and DISP4 in turn.

This on-off switching of the displays is done at such a fast rate (around 2kHz) that the displays all appear to be continuously lit.

Display dimming

Light-dependent resistor LDR1 is used to sense the ambient light to control the display dimming. This is connected in series with a 22kΩ resistor to form a voltage divider across the +5V rail, and its output is fed to IC1's AN3 port.

When the ambient light is high, the LDR has a low resistance and the voltage at the AN3 input is pulled down close to 0V. Conversely, in low ambient light, the LDR has a high resistance and IC1's AN3 input is pulled close to the +5V rail via the 22kΩ resistor. At intermediate light levels, AN3 will sit somewhere between 0V and +5V.

In operation, IC1 dims the displays in response to its AN3 voltage. It does this by limiting the amount of time that the displays are lit. In bright light, each display is lit for almost 25% of the total time, but this reduces as the AN3 voltage rises in response to falling light levels.

In fact, at very low levels, each display might only be lit for about 2% of the time.

Pushbutton switches

Switches S1 to S4 allow the unit to be programmed by providing the Mode, Select, Down and Up functions. These are connected respectively to the bases of transistors Q1 to Q4, while the other ends are commoned and connected to the +5V rail via a 10kΩ resistor. This commoned end is also connected to IC1's AN2 input, which monitors the switches.

If switches S1 to S4 are all open, IC1's AN2 input will be held at +5V via the 10kΩ pull-up resistor. However, if a switch is closed, AN2 is connected to the base of its corresponding transistor. As a result, the voltage on the AN2 input will drop to about 0.6V below the +5V rail (ie, to 4.4V) each time that particular transistor switches on.

In operation, the microcontroller periodically checks the voltage at its AN2 input. As a result, it can decide if a switch has been closed based on the AN2 voltage and then determine which switch it is by checking which transistor is currently switched on.

The optional external Alternative Display Switch is connected in parallel with switch S4. This switch can be a dashboard toggle switch so that, for example, either the air/fuel ratio or the lambda value can be shown. Alternatively, it can be a relay contact that automatically opens or closes depending on the fuel (eg, petrol or LPG).

Note that this switch is not required if the display only needs to show one set of values.

Input signal

The signal from the sensor is fed to the AN4 pin of IC1. IC1 converts this input voltage into a 10-bit digital value, which is then processed and the resulting calculation fed to the display.

A 2.2kΩ current-limiting resistor and internal clamping diodes inside IC1 protect the AN4 input should the input voltage go above the +5V supply or below the 0V rail. The associated 10nF capacitor filters any voltage spikes at the input.

A feature of the unit is that it switches off all the displays for a short period be-

Parts List – Oxygen Sensor Display

1 double-sided PC board, code 825, available from the *EPE PCB Service*, size 80mm × 50mm
1 plastic case measuring 83mm × 54mm × 31mm
1 rectangular piece of red clear Perspex 48mm × 18mm
4 SPDT micro tactile switches, with a 6mm actuator (S1 to S4)
1 LDR with 48kΩ light resistance
1 DIP20 IC socket, 0.3-inch width
1 DIP18 IC socket
1 DIP16 IC socket
1 DIP14 IC socket
1 M3 x 10mm screw
1M3 nut
5 PC stakes
1 2m length of twin shielded wire

Semiconductors
1 PIC16F88-I/P programmed microcontroller (IC1)
3 13mm common anode LED displays (DISP1-DISP3)
1 10-LED DIL bargraph (DISP4)
4 BC327 *PNP* transistors (Q1-Q4)
1 LM2940CT-5, +5V low dropout regulator (REG1)

Capacitors
1 220µF 10V radial electrolytic
1 470nF MKT polyester
1 100nF MKT polyester
1 10nF MKT polyester

Resistors (0.25W, 1%)
6 2.2kΩ
1 10kΩ
1 22kΩ
1 5 × 100Ω individual SIL resistor array
1 3 × 100Ω individual SIL resistor array

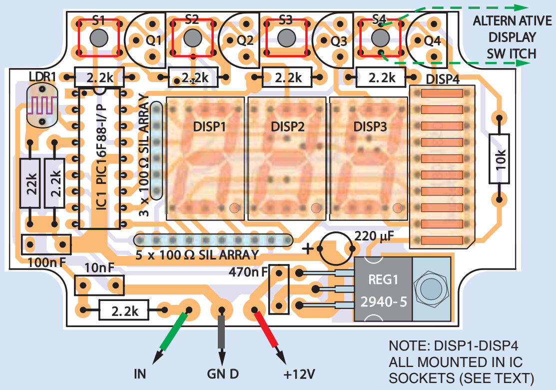
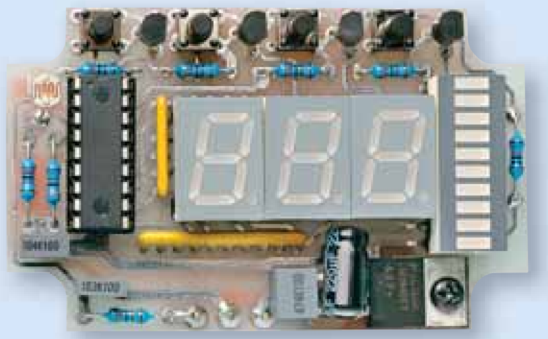
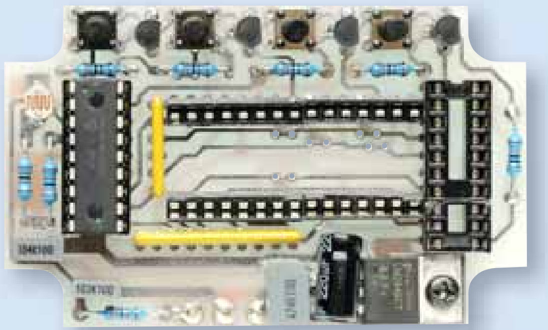


Fig.6: install the parts on the PC board as shown here. The alternative display switch is optional (see text).



Take care to ensure that all the parts are installed on the PC board with the correct orientation. The LED bargraph is mounted with its bevelled edge at bottom right (see Fig.6).



This view shows the PC board before the 7-segment LED displays and the bargraph are plugged in.

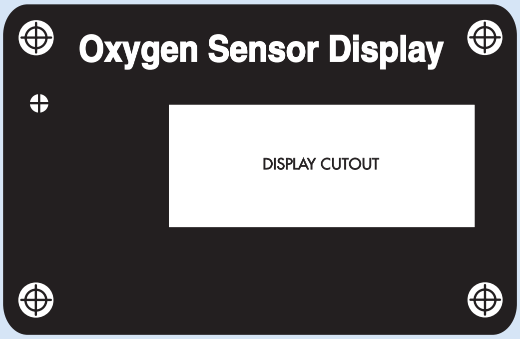


Fig.7: this full-size artwork can be used as a drilling template for the front panel.

fore measuring the input voltage. This minimises any voltage drops that could occur due to supply current in the ground wiring if the displays were lit, and ensures accurate measurements.

Timing for IC1 comes from an internal oscillator running at 4MHz. This has an accuracy of about 2%, which is close enough for this application, as the timing is not critical.

Power supply

Power is derived from the vehicle's fused ignition supply. This +12V rail is fed to a low-dropout LM2940CT-5 +5V regulator. These regulators are designed for automotive applications and are protected against line transients and reverse supply voltage (if the supply is reversed, the output remains at 0V and no damage occurs).

A 470nF capacitor decouples the supply for the regulator input, while a 220µF capacitor filters the +5V output. This output capacitor supplies the transient current required for the displays and also prevents the regulator from becoming unstable.

In addition, the supply rail to IC1 is decoupled using a 100nF capacitor at pin 14. The 2.2kΩ resistor between IC1's $\overline{\text{MCLR}}$ input (pin 4) and the +5V rail provides the power-on reset signal for IC1.

Software

The software program files for the *Wideband Oxygen Sensor Display* will be available from the *EPE* website at: **www.epemag.com**.

Construction

This unit is easy to assemble, with all parts installed on a double-sided PC board. This board is coded 825 (80mm × 50mm) and is housed in a small plastic case measuring 83mm × 54mm × 31mm.

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	6	2.2kΩ	red red red brown	red red black brown brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	22kΩ	red red orange brown	red red black red brown
❑	8	100Ω	brown black brown brown	brown black black black brown

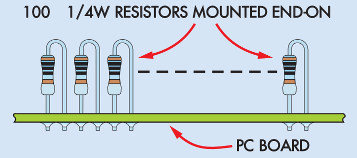


Fig.8: separate 100Ω resistors can be used instead of the two resistor arrays. Mount them as shown here.

The PC board is available from the *EPE PCB Service*. Our board does ***NOT*** have plated through holes and will require 'vias' and some components soldered to both sides.

Begin by checking the board for any defects and by checking the hole sizes for the major parts. Check also that the PC board is cut and shaped to size so that it clips into the integral side slots in the case.

Fig.6 shows the parts layout. Install the resistors first, taking care to place each in its correct position. Table 1 shows the colour code values, but you should also use a digital multimeter to check each resistor before installing it. Note that the 100Ω resistors are in single in-line (SIL) resistor arrays. However, you can also use standard 0.25W resistors here and these can be installed by mounting them end-on, as shown in Fig.8.

Next, install the PC stakes. These are installed from the underside of the PC board at the three external wiring positions (the external wiring connects to the rear of the board).

Transistors Q1 to Q4 can go in next and these must be installed so that their tops are no higher than 12mm above the PC board. Follow them with the four switches (S1 to S4). These switches can only go in with the correct orientation, so if the holes don't line up, simply rotate them by 90°

REG1 is next on the list. This device mounts horizontally on the PC board, with its leads cranked down through 90° so that they pass through their corresponding holes. Secure its metal tab to the board using an M3 × 6mm screw and nut before soldering its leads.

Once it's in, install the capacitors. Note that 220µF electrolytic adjacent to REG1 is installed with its leads bent through 90°. Its body lies horizontally across the regulator's leads, as shown in the photo.

How the micro calculates the values

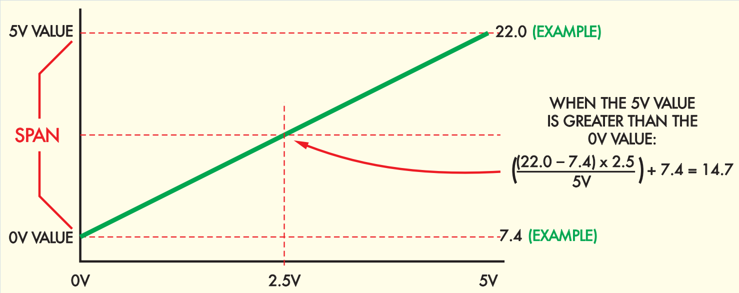


Fig.9: this graph shows how IC1 calculates the display values when the 5V endpoint value is greater than the 0V endpoint value. This example uses 7.4 and 22.0 for the 0V and 5V endpoint values respectively, giving a 2.5V sensor output value of 14.7 (ie, stoichiometric for unleaded petrol).

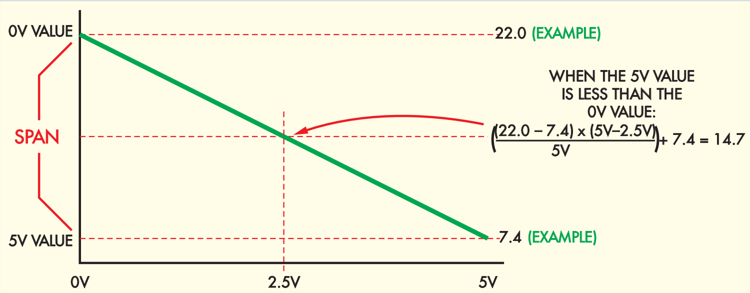


Fig.10: the equation is slightly different when the 0V endpoint value is greater than the 5V endpoint value. In this example, 22.0 has been used for the low endpoint value, while 7.4 has been used for the high endpoint value.

To set the values for the display, you only need to set the endpoint values at 0V and at 5V. The internal microcontroller then processes the input signal and calculates the correct vales for display.

For example, if the 0V endpoint value is 7.4 and the 5V endpoint value is 22.0, a 2.5V input will give a display reading of 14.7 for the air/fuel ratio. This is calculated by first subtracting the low endpoint value from the high endpoint value to get the span value (in this case, 22 – 7.4 = 14.6). This span value is then multiplied by the input voltage, divided by the 5V range and finally added to the low endpoint value (7.4 in our example). Fig.9 shows this in graphical form.

If the unit is set up so that the 0V endpoint value is higher in value than the 5V endpoint value, then the calculation is different (see Fig.10). In this case, the 5V endpoint value is subtracted from the 0V endpoint value to get the span value. This value is then multiplied by the difference between the input voltage and 5V, after which the result is divided by 5V and added to the 5V endpoint value. Fig.10 shows the equation for endpoint values of 22 and 7.4.

Note that in both cases, the 5V value assumes that the reference voltage used in the Oxygen Sensor Display is exactly 5V. However, the reference voltage from the regulator that's used could be anywhere from 4.85-5.15V, so there is an adjustment to compensate for this.

If the reference voltage is below 5V, then the Oxygen Sensor Display will not show readings for input voltages that are higher than this reference. Conversely, if the reference is above 5V, then the unit will show readings for input voltages only up to the +5V. By compensating for this reference voltage, the correct value will be shown on the display.

In practice, the regulator used for the reference is trimmed during manufacture and its output will probably be very close to +5V.

Changing the wideband display settings

THE four pushbutton switches inside the case are for Mode (S1), Select (S2), Down (S3) and Up (S4).

Pressing the Mode switch initiates the **Settings** mode. Pressing it again returns the display to the normal **Run** mode so that it shows the values in response to the input voltage.

Once in the **Settings** mode, you can alter the way the display operates. You can set how the dimming works, set the regulator voltage, alter the 'A' or 'B' values selection and alter the 0V and 5V endpoint values for each selection. In addition, you can change the bargraph display from dot to bar, or to a centred bar.

The bargraph is used to indicate which setting is selected. In this mode, the lower LED (LED8) is always lit – see Fig.11 (note: LED8 is never lit in the normal run mode).

The remaining LEDs on the bargraph show which setting has been selected (see Fig.11). Note that there are 10-LEDs on the bargraph, but only the middle eight (designated LEDs1-8) are used. **You cycle through the settings by pressing the Select switch (S2)**.

Minimum Display Brightness: when LED7 is lit, the setting is for the Minimum Display Brightness that occurs when the LDR is in complete darkness. This value is initially set at '14', as shown on the display.

When adjusting this value, it's necessary to cover the LDR so that it does not receive any ambient light, either from below or above its surface. A black film canister is ideal for this; the value is adjusted using the Up and Down switches to set the desired minimum brightness.

The absolute minimum brightness is reached at 0, but typical settings would range from 10 to 30.

Dimming Threshold: pressing the Settings switch again brings up the Dimming Threshold setting, with LED6 lit. This is initially set at 200 and determines the ambient light level below which dimming begins. Increasing the value means that dimming begins at a higher ambient light level, while decreasing the value sets the dimming to begin at a lower light level.

Regulator Voltage: the next setting is for the Regulator Voltage (LED5 lit). This value is initially set at 5.00V, and is normally adjusted (using the Up and Down switches) to agree with the actual regulator output voltage, as measured between its OUT and GND terminals.

A Or B Display: LED4 indicates the A or B Display selection. Here, you can select between the 'A' and 'B' display values. If 'A' is selected, then the normal Run mode will show the 'A values and the 'B' value can be shown by pressing S4 (Up) or by using the external alternative display switch.

Alternatively, if the 'B' values are selected, the display will show these in Run mode and the 'A' values will be shown if S4 is pressed (or the external switch is toggled).

Display Format: the Display Format is next in the sequence (LED3 lit). In this case, the digital display will show A.AA, AA.A or AAA for the 'A' selection. You can select the decimal point position using the Up or Down switches. Similarly, if the 'B' values have been selected, the display will show b.bb, bb.b or bbb.

0V Display Value: pressing S1 again to light LED2 selects the 0V Display Value. This is the value that's displayed in Run mode when the input is at 0V. It can be set to any value from 0 to 999. Note that this value will be for the 'A' display if this was previously selected in the 'A Or B Display' option. Alternatively, this value will be for the 'B' display if this was previously selected in the display option.

Note that where the 'A' and 'B' displays both need to be set, it will be necessary to temporarily change the display option from 'A' to 'B' or from 'B' to 'A' and also set the required Display Format before adjusting the endpoint value to suit the alternate display.

5V Display Value: The 5V Display Value setting is indicated when LED1 is lit. Again, you can set this to any value from 0 to 999 and the same comments as above apply to setting values for both 'A' and 'B' displays.

It's important to note here that the 0V and 5V values must match the output from the wideband controller.

Mounting the displays

The 7-segment LED displays and the 10-LED bargraph are raised up off the PC board using IC sockets.

The sockets for the 7-segment displays are made using a 16-pin DIP socket and a 14-pin DIP socket. These are cut into strips of two 8-pin and two 7-pin SIL sockets using a small hacksaw. One 8-pin and one 7-pin strip is then installed along the top edge of the display positions, while the remaining 8-pin and 7-pin strips are installed along the bottom edge (ie, the sockets form two 15-pin strips).

Once these SIL strips are in, install a 20-pin DIP socket for the LED bargraph and an 18-pin DIP socket for IC1. Be sure to orientate the socket for IC1 with its notched end towards the top (ie, towards the 2.2kΩ resistor). Don't plug the displays or IC1 in yet, though.

Finally, install the LDR (either way around) so that its top surface is 15mm above the top of the PC board.

Testing

Now for the smoke test, but first go over the board carefully and check for incorrect component placement and for missed or shorted solder joints.

Next, with IC1 out of its socket, apply power to the +12V and GND terminals and check that 5V is present between pins 14 and 5 of IC1's socket. If this is correct, switch off and install IC1 and the displays. DISP1, DISP2 and DISP3 mount with the decimal points to bottom right, while DISP4 (the LED bargraph) mounts with its chamfered edge at bottom right (note: the chamfer is quite subtle). IC1 goes in with its notched end towards the top.

When power is now reapplied you should be greeted with a display on the 7-segment digits and the bargraph. If not, check the orientation of IC1. If

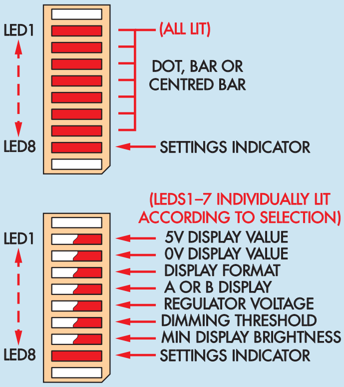


Fig.11: this diagram shows the bargraph setting indications for the default wideband operating mode.

This means that if you set the wideband controller to deliver air/fuel ratios over a range of 7.4 to 22.0, then the display should also be set to these values.

If you want to have the stoichiometric value in the middle of the scale (so that the bargraph display is centred), then the sum of the 0V endpoint value and the 5V endpoint value must be twice the stoichiometric value. So, if the stoichiometric air/fuel ratio is 14.7, the 0V endpoint value and the 5V endpoint value must add up to 29.4 – eg, you could use 7.4 and 22.0 as the endpoints.

If you intend to display the lambda value, then the minimum and maximum values must add up to 2 (eg, 0.52 and 1.48 could be used, but other values could be used instead).

Bargraph Display Option: the final selection brings up the Bargraph Display Option, and in this case all eight LEDs are lit. Again, the options are selected using the Up and Down switches and are as follows: (1) dot (shown as **doT** on the display); (2) bar (shown as **bAr** on the display); and (3) centred bar (shown as **bCn**). Note that the 'T' in the doT lettering has the left-hand side of its cross piece located over the 'o'.

The default setting for the bargraph display is to have the LEDs progressing upwards with increasing sensor output voltage. Conversely, if you want them to progress upwards with a falling sensor voltage, then it's just a matter of selecting the inverse, as follows.

To invert the 'A' curve selection, press S2 at power up and the display will show the current selection. Initially, this will show 'A.ni'(A not inverted) and this indicates that the A bargraph is not inverted. If S2 is now held pressed for four seconds, the display will change to show 'A. i' (A inverted) to indicate that the bargraph operation is now inverted.

You simply release the switch when the required selection is displayed. Holding the switch down will cause the display to cycle between the inverted and non-inverted options.

Similarly, to set the 'B' bargraph sense, S3 is pressed when power is applied. This will initially indicate 'b.ni' (B bargraph not inverted) but can be changed to 'b.i' (B bargraph inverted) by holding the switch down for four seconds.

It's easy to check the current selection by pressing S2 or S3 at power up. No changes will occur unless the switch is held for more than four seconds and the display changes to the next option.

that's correct, check that transistors Q1 to Q4 are BC327 *PNP* types.

Final assembly

As mentioned earlier, the PC board is designed to simply clip into the specified plastic case. A 48mm × 18mm cutout is made in the lid of the box for the displays and this cutout is fitted with a red Perspex filter. In addition, a hole is drilled in the lid for the LDR, so that it is exposed to the ambient light.

A hole at the rear of the box allows the wiring to exit from the case.

The front-panel artwork shown in Fig.7 can be used as a template for cutting and drilling the holes. It can either be scanned or photocopied and temporarily affixed to the lid using double-sided tape.

The cutout for the LED displays can be made by drilling a series of small holes inside the inside perimeter of the cutout, and then knocking out the centre piece. The cutout is then carefully filed to a smooth finish.

The hole for the LDR should be drilled to 5mm, as should the exit hole in the back of the case. This exit hole should be positioned near the bottom edge of the case, so that it will directly line up with the PC stakes on the back of the board. Alternatively, you can drill the hole to 9.5mm and fit it with a 6mm, inside diameter, rubber grommet.

Making the connections

We used twin-shielded wire for the power and input connections, but automotive wire could also be used. **Connect the +12V lead to the fusebox in the car so that the Oxygen Sensor Display is powered only when the ignition is on (ie, be sure to connect to the fused side).** The ground connection should preferably connect to the same ground as the wideband controller.

For narrowband use, connect the ground to the same ground as the sensor. The input lead for the Oxygen Sensor Display is connected either to the 0V to 5V output from the wideband controller or (if you are saving money) to a narrowband sensor signal.

Fit a cable tie around the leads on the inside of the box, to prevent them being pulled out of the hole.

Setting up

For use with a wideband controller, the unit is set up as described in the panel titled 'Changing The Wideband Display Settings'.

Note that commercial wideband controllers can have either fixed or adjustable endpoint values. The adjustable versions have their endpoints set by connecting them to a computer. **Note also that the endpoint values programmed into the display unit must match those of the wideband controller. This ensures that the unit is correctly calibrated and gives accurate air/fuel ratio readings.**

Switching between the 'A' and 'B' display values (eg, between air/fuel ratio and lambda values, or between unleaded petrol and LPG air/fuel ratios) can be achieved by wiring an external switch (or NO relay contacts) in parallel with switch S4 (see Fig.6).

Note that the connections on the relay contacts or switch must be solely for this purpose. If you need to switch a fuel valve or anything else at the same time, use a double-pole relay or switch.

Using the unit with narrowband sensors

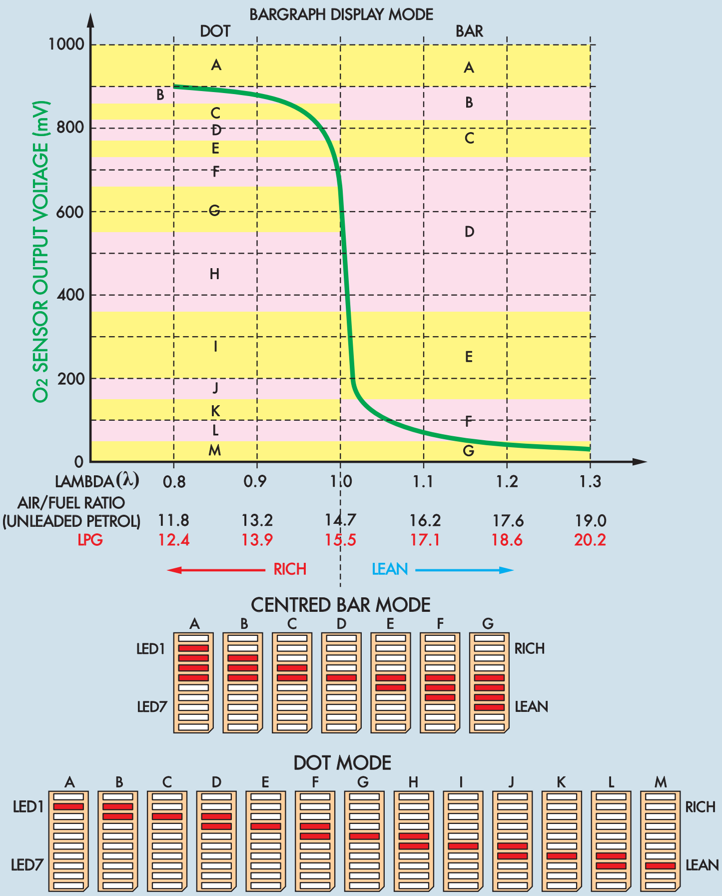


Fig.12: two bargraph options are available when the unit is set to operate in narrowband mode – either centred bar mode or a 13-step dot mode. The S-curve graph at top indicates which bargraph LEDs light in response to the various sensor output voltages.

WHEN used with narrowband sensors, this unit will display air/fuel ratios that are calibrated to the S-curve output of a Bosch LSM11 narrowband oxygen sensor. Note, however, that this may not be accurate for other oxygen sensors.

In the case of the LSM11, it shows air/fuel ratios for unleaded petrol from 11.8 to 20.6, with the stoichiometric ratio set for 14.7. For air/fuel ratios below 11.8, the unit will show an 'r' for rich, while for ratios above 20.6 the unit shows an 'L' for lean.

For LPG, the range is from 12.6 to 21.4 with the stoichiometric point at 15.5. The unit displays an 'r' (rich) for ratios below 12.6 and an 'L' (lean) for ratios above 21.4.

For narrowband sensors, the bargraph options are as shown in Fig.12; ie, either a centred-bar mode or a 13-level dot mode. These 13 different levels are achieved by lighting either one or two LEDs at a time.

For the bar mode, the centre LED is always lit and is the only LED that is lit at stoichiometric. The bar then progresses upwards from the middle LED for richer mixtures or below the middle LED for leaner mixtures.

Enabling the S-curve response

Enabling the narrowband S-curve response is easy: just press and hold the Mode switch as power is applied.

The display will then indicate the current display mode setting. This can be either the Linear (wideband) mode, the S-curve unleaded mode or the S-curve LPG mode. If the switch is released before four seconds, the current display mode will not be altered. Conversely, if the switch is held down, the mode will cycle from one to the other at a nominal four-second rate. You simply release the switch when the required display mode is shown.

It's also easy to tell which mode the unit is in. The display will show 'Lin.' for the linear mode (or wideband mode), while the two S-curve modes are shown as S.UL (S-curve unleaded) and S.LP (S-curve LPG).

Pressing the Mode switch after power-up has been applied initiates the **Settings** mode. As before, this allows you to alter the way the display operates. You can adjust how the dimming works, set the regulator voltage, alter the unleaded or LPG selection and change the bargraph display from dot mode to centred bar mode.

As in wideband mode, the bargraph LEDs are again used to indicate which setting has been selected. These settings are somewhat different for the narrowband S-curve modes, but are altered in exactly the same manner.

Fig.13 shows the details. As before, only eight LEDs in the 10-LED bargraph are used and the lower LED (LED8) is always lit in the settings mode. The remaining LEDs on the bargraph show which setting has been selected and you can cycle through these settings by pressing switch S2.

Minimum Display Brightness: when LED7 is lit, the setting is for the Minimum Display Brightness that occurs when the LDR is in complete darkness. This value is initially set at '14', as shown on the display.

When adjusting this value, it's necessary to cover the LDR so that it does not receive any ambient light either from below or above its surface. A black film canister is ideal for this, and the value is adjusted using the Up and Down switches to set the desired minimum brightness.

The absolute minimum brightness is reached at 0, but typical settings would range from 10 to 30.

Dimming Threshold: pressing the Settings switch again brings up the Dimming Threshold setting, with LED6 lit. This is initially set at 200 and determines the ambient light level below which dimming begins. Increasing the value means that dimming begins at a higher ambient light level, while decreasing the value sets the dimming to begin at a lower light level.

Regulator Voltage: the next setting is for the Regulator Voltage (LED5 lit). This value is initially set at 5.00V and is normally adjusted (using the Up and Down switches) to agree with the actual regulator output voltage, as measured between its OUT and GND terminals.

The regulator voltage adjustment can also be used to alter the unit's response to the oxygen sensor's output. For example, setting the regulator voltage to a value that's higher than the actual regulator voltage results in the unit displaying its full range of air/fuel values over a reduced voltage range. It effectively lowers the rich end of the S-curve, so that rich readings are indicated at lower oxygen sensor voltages.

Similarly, setting the regulator voltage value lower than the real regulator voltage increases the voltage range. This raises the rich end of the S-curve and rich readings are shown at higher oxygen sensor voltages.

Basically, this adjustment can be used to provide a more accurate air/fuel reading for the particular oxygen sensor used.

Unleaded Or LPG Display: LED4 indicates the Unleaded Or LPG Display setting. This can be toggled using either the Up or Down switch between S.UL (for unleaded petrol) or S.LP (for LPG). When normal mode is resumed, the display will then show the air/fuel ratio values for the selected fuel.

As before, the unit can be set up for both unleaded petrol and LPG, with the display reading toggled using an external switch wired across S4. When this switch is open, the default air/fuel readings (as selected in the preceding paragraph) are displayed.

Bargraph Display Options: finally, S1 is pressed again to bring up the Bargraph Display Options (all 8-LEDs are lit). Again, these are selected using the Up or Down switch and you can choose either the centred bar mode (shown as **bCn** on the display or the 13-step dot mode (shown as **doT**). *EPE*

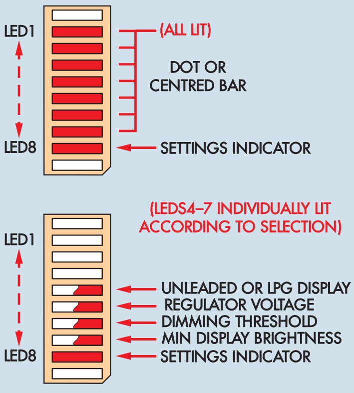
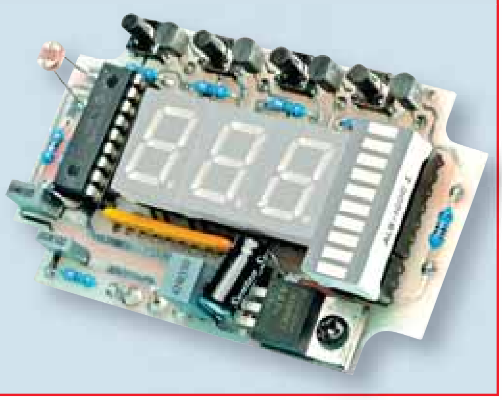


Fig.13: the setting indications for the narrowband mode. This mode is initiated by pressing and holding the Mode switch as power is applied.



A high-quality stereo DAC for superb sound from your DVD player

Part 2: by NICHOLAS VINEN

Board assembly details

Last month, we introduced our new high-quality Stereo Digital-To-Analogue Converter (DAC) and described the circuit. This month, we show you how to build the various modules and make the header cables.

AS SHOWN in the photos, our prototype DAC was built into a single-unit, high rack case with internal rails from Jaycar. However, the internal rails (used to secure the panels) make it difficult to mount the two main PC board assemblies. In the prototype, these boards were mounted on the rails but it really is an exercise in frustration when it comes to fitting the nuts to the mounting screws.

What's more, once they are in and the case is fully assembled, it's a big job to remove them again – the choice is yours!

Another problem is the sub-panel that runs just behind the front panel. This complicates matters when it comes to mounting both the mains power switch and the Front Panel Switch Board because it means that additional cut-outs are necessary.

Finally, making sure that all the panels and rails are properly earthed is a difficult and time-consuming task.

PC board assembly

We explained last month that the Stereo DAC is built on four PC boards: (1) an Input Board, (2) a DAC Board, (3) a Front Panel Switch Board and (4) a Power Supply Board. They are all straightforward to assemble although there are two surface-mount ICs (IC3 and IC6) to consider, one on the Input Board and the other on the DAC Board. All the above boards are available from the *EPE PCB Service* as a set.

TOSLINK receivers

Jaycar ZL-3003 TOSLINK receivers were specified for this project in the parts list published last month. However, some component suppliers may supply a 3.3V TOSLINK (optical) receivers.

The only problem is that the Jaycar units run off 5V, whereas the alternative units require a 3V rail. As a result, we have slightly modified the PC board so that either receiver can be used. This involved fitting a 3-pin header near TOSLINK1 on the Input Board, so that a shorting jumper can be used to select between +5V and +3.3V rails (3.3V is close enough).

It's just a matter of fitting the jumper to select the +5V rail if you are using Jaycar ZL-3003 receivers or fitting it to select 3.3V receivers.

Check carefully if you buy TOSLINK receivers elsewhere – not only can their supply requirements vary, but they may not have the same pinouts.

The bad news here is that you will have to be extra careful when soldering the two (IC3, IC6) surface-mount devices on the reverse side of the PCBs. It is possible to reliably hand-solder these TSSOP (Thin Shrink Small Outline Package) parts. The good news is, the article *How To Solder Surface-Mount Devices* (*EPE* July '10) describes how it is done.

Begin PCB construction by carefully inspecting all four boards for possible defects. Make sure that there are no shorted or broken copper tracks and check that all the holes have been drilled. In particular, pay special attention to the area immediately surrounding the surface-mount ICs on the Input and DAC Boards, as these have very fine tracks and close track clearances.

Having done this, start the assembly by building the Input Board. This board is coded 820 and measures 113mm × 93mm. Fig.5 shows the assembly details.

The first step is to install IC3. This is a 28-pin TSSOP SMD, which has a 0.65mm pin pitch (ie, there is 0.65mm between the centres of adjacent pins). The clearance between the pins is a mere 0.35mm, which means that it is almost impossible to manually solder the pins one at a time without bridging them.

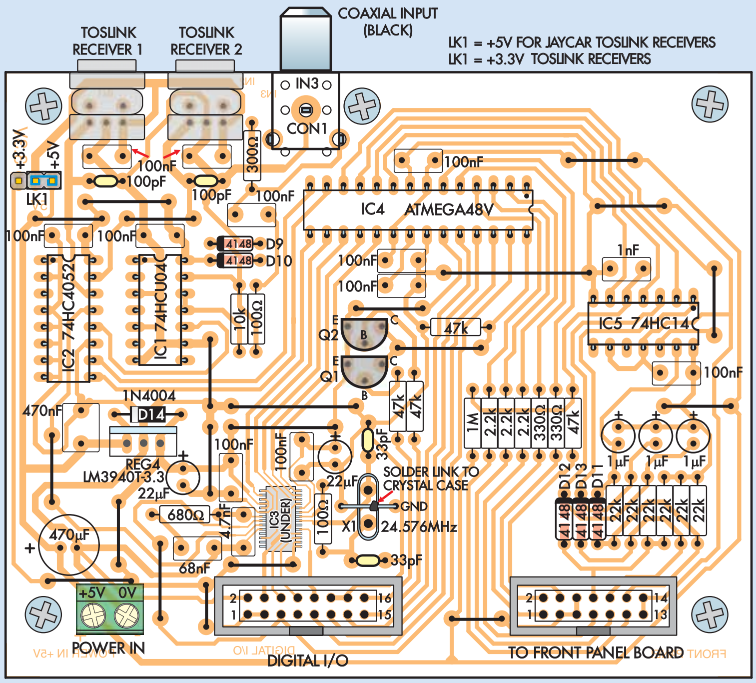


Fig.5: the parts layout on the Input Board. Make sure the SMD device (IC3) is installed first (see Fig.6) and be sure to select the correct supply rail option to suit your TOSLINK receivers.

Fig.6: You will have to carefully solder IC3 (surface-mount) by hand, as shown here.

DETAIL VIEW OF UNDERSIDE OF PC BOARD SHOWING IC3

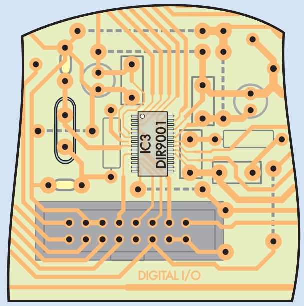


Fig.6 shows where IC3 is installed. This SMD part is mounted on the copper side of the board and must be oriented with its pin 1 at upper left, as shown. It's easy to identify pin 1 – it's adjacent to a small dot in the body at one end of the IC. Refer to the article referenced on the previous page for all the details on soldering it into place.

Fig.5 shows how the rest of the parts are installed. Start by installing the 21 wire links (use 0.71mm tinned copper wire), then install the resistors. Table 1 shows the resistor colour codes for this board, but check each one using a digital multimeter before installing it, just to make sure.

Follow these parts with the diodes. These are all 1N4148s except for D14, which must be a 1N4004. Check that they are all correctly oriented before soldering their leads.

The four IC sockets are next on the list. Install these with notched ends matching the notches on the overlay. In each case, it's usually easier to first solder two pins at opposite corners, then check that the socket is sitting flat against the PC board before soldering the remaining pins.

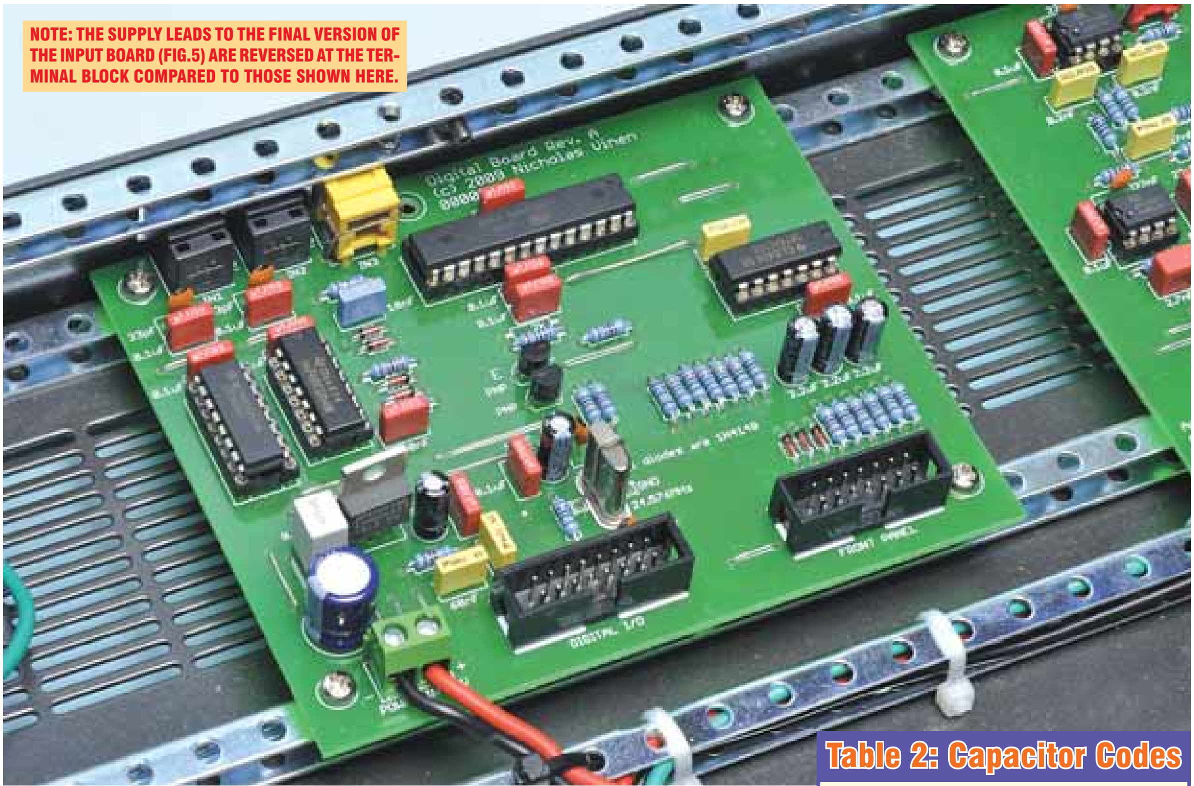
The two IDC sockets (14-pin and 16-pin) go in with their notched sides oriented as shown (ie, towards the edge of the PC board). Don't get them in the wrong way around. Alternatively, you can use DIL pin headers (0.1-inch spacing) instead of the IDC sockets, although these make it possible to plug a connector in backwards, which could damage some components.

Once these parts are in, install the 2-way screw terminal block, then install all the MKT and ceramic capacitors. If your 33pF ceramic capacitors have a 5.08mm (0.2-inch) pin spacing, they will fit right into the holes. If not, use a pair of thin-nosed pliers to carefully bend the legs out at approximately 45° and then parallel again so that they fit.

Follow with the six electrolytic capacitors (make sure they are correctly oriented) and the two BC327 transistors

Table 1: Resistor Colour Codes – Input Board

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	1MΩ	brown black green brown	brown black black yellow brown
❏	4	47kΩ	yellow violet orange brown	yellow violet black red brown
❏	6	22kΩ	red red orange brown	red red black red brown
❏	1	10kΩ	brown black orange brown	brown black black red brown
❏	3	2.2kΩ	red red red brown	red red black brown brown
❏	1	680Ω	blue grey brown brown	blue grey black black brown
❏	2	330Ω	orange orange brown brown	orange orange black black brown
❏	1	300Ω	orange black brown brown	orange black black black brown
❏	2	100Ω	brown black brown brown	brown black black black brown



This close-up view shows the fully-assembled prototype Input Board (it differs slightly from the final version) Take care with component orientation.

(Q1 and Q2). Just line up the flat sides of the transistors, as shown on Fig.5, and you can't go wrong.

TOSLINK receivers

The two TOSLINK receivers go in at top left of the board and can only go in one way. They should be installed one at a time. In each case, after you insert the five pins through the holes, gently push the module towards the middle of the board. This will ensure that the plastic feet correctly sit near the edge of the board and that the face is parallel with the edge.

Solder the two thicker pins closer to the PC board edge first, then check that it is sitting flush against the board and is correctly aligned. Adjust it if necessary before soldering the remaining three pins.

The 3-pin header (near TOSLINK1) can now go in. This header allows you to select the supply rail for the TOSLINK receiver using a shorting jumper. **Place the jumper in the 5V position (as shown on Fig.5) if you have the Jaycar ZL-3003 receivers.**

Alternatively, fit the jumper to the 3.3V position if you use the 3.3V type receivers.

A black RCA phono socket is used for the coaxial input, which can be a little tricky to fit. You may have to press it fairly hard into the holes to get it to sit properly. Note that the six plastic posts don't actually go down very far into the holes – the metal flange on the centre pin usually limits this. Adjust it so that it is at right angles to the PC board, then solder the two pins on either side. That done, recheck the orientation before soldering the third pin.

Next on the list is the 24.576MHz crystal. Once you have soldered its leads to the board, cut a length of 0.71mm tinned copper wire and bend it into a U-shape. Insert the ends of this wire into the holes on either side of the crystal and push it down so that the 'U' sits flat against the top of the crystal case.

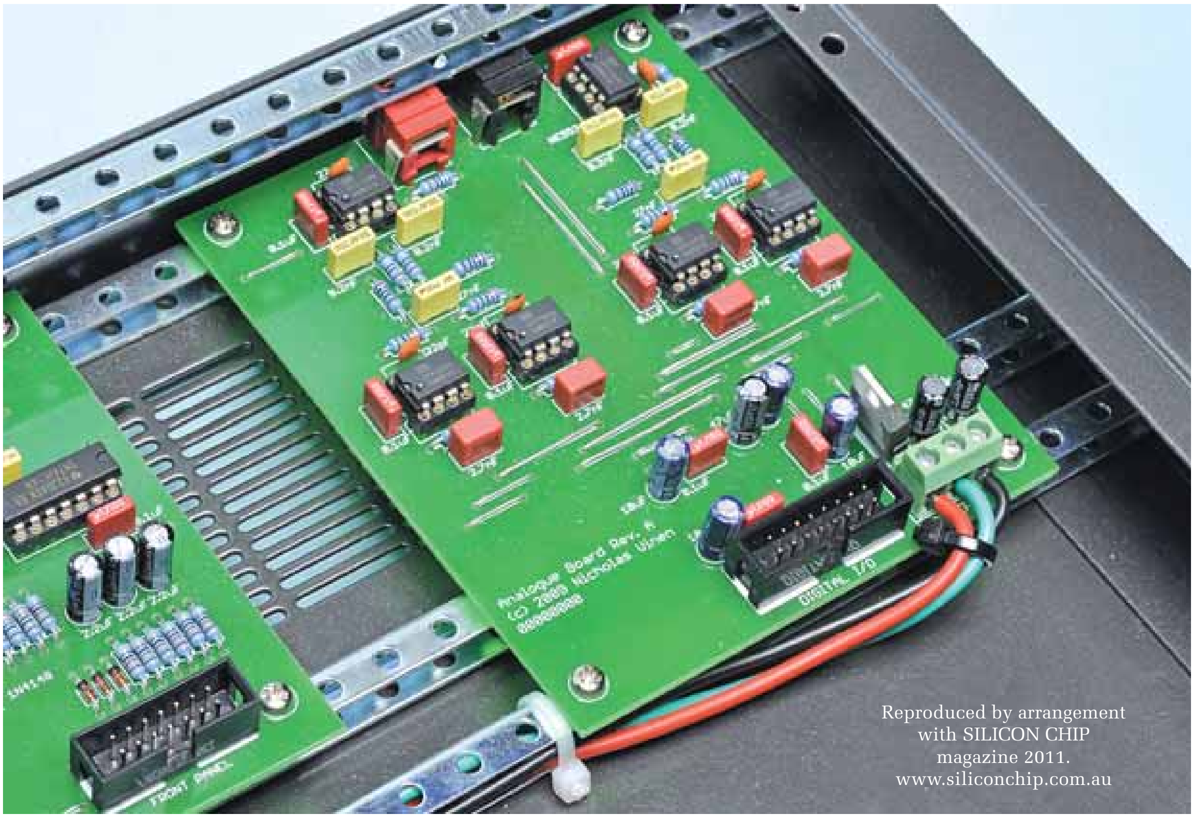
Finally, solder both ends of the wire to their PC pads, then solder the top of the 'U' to the crystal's case to ensure good electrical contact. Doing this 'grounds' the metal case and reduces RF interference.

The Input Board assembly can now be completed by installing regulator REG4 and by plugging the ICs into their sockets. Note that REG4 goes in with its metal tab towards diode D4. Push it down onto the PC board as far as it will comfortably go before soldering its leads.

Take care when fitting the ICs – they must be fitted with the notched ends oriented as shown. Also, be careful not to get IC1 and IC5 mixed up, they are both 14-pin devices.

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
68nF	.068µF	68n	683
27nF	.027µF	27n	273
10nF	.01µF	10n	103
8.2nF	.0082µF	8n2	822
4.7nF	.0047µF	4n7	472
2.7nF	.0027µF	2n7	272
2.2nF	.0022µF	2n2	222
1nF	.001µF	1n0	102
33pF	NA	33p	331
22pF	NA	22p	221



The DAC board is mounted in the rear right-hand corner of the case. Use a white phono socket for the left output and red for the right (not red and black as fitted to the prototype).

Building the DAC Board

Refer now to the component layout diagram of Fig.7 to build the DAC Board. This board is coded 821 (94mm × 110mm) and is assembled in exactly the same manner as the Input Board.

Once again, you must be extra careful when soldering the SMD IC (DSD1796) into place. You will need to install it as shown in Fig.8. As before, this device is mounted on the copper side of the PC board and is installed in exactly the same manner as IC3. Make sure that it's mounted with pin 1 at lower left, as indicated by Fig.8.

That done, install the wire links, resistors, IC sockets and capacitors. Diode D15 (1N4004) and regulator REG5 can then be installed, making sure they are oriented as shown.

Follow these parts with the 16-pin IDC header and the two RCA phono output connectors. Be sure to follow convention and use a red socket for the right output and a white socket for the left output. Check that the sockets sit flush against the PC board and are aligned at right angles to it before soldering their leads.

Finally, complete the DAC Board assembly by fitting the ICs into their sockets. **OPA134 op amps are recommended for IC7 to IC12 but you can also use NE5534s for slightly reduced performance.**

Front Panel Switch Board

The Front Panel Switch Board is coded 822 (103mm × 34mm) and carries only a handful of parts: the three pushbutton switches, two 5mm LEDs, infrared receiver IRD1, a 100nF capacitor and a 14-pin DIL header. In addition, you have to install two wire links.

It should only take you about 15 minutes to assemble, but note that the switches, IRD1 and the two LEDs are all installed on the copper (track) side of the PC board. Fig.9 shows the details.

Begin construction by installing the two wire links, the IDC socket and the 100nF MKT capacitor on the non-copper side of the PC board. **Be sure to orient the IDC socket correctly, ie, notched side towards the top of the board.**

Once these parts are in, temporarily install an M3 × 10mm tapped spacer at each corner, with the spacers on the non-copper side and M3 machine screws passing through from the copper side (you can use the spacers that will later be fitted to the Input or DAC boards). This will ensure that the assembly will now sit level on your workbench and will make it easier to install the pushbutton switches.

Installing the three specified pushbutton switches on the copper side of the board is the next step. These have angled pins at each corner, plus two straight pins for the integral blue LED. The anode of the LED is longer than the cathode, and must go into the hole marked 'A' on the overlay (ie, towards the DIL header).

Once the pins are inserted through the holes, press the buttons down gently. Because of the way the corner

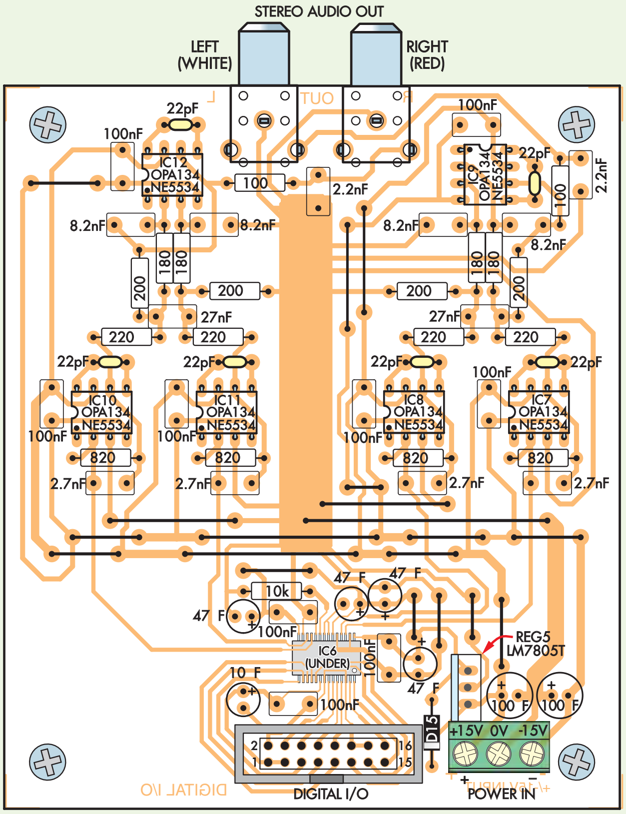


Fig.7: the DAC/output Board is easy to assemble, but make sure that the SMD (IC6) is installed first.

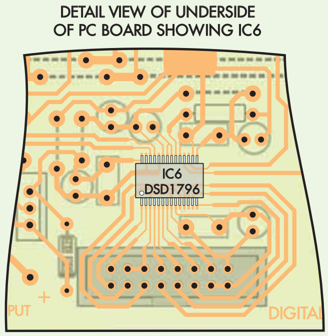


Fig.8: install IC6 on the copper side of the PC board, as shown here.

pins are bent, they should not go all the way through. If one of the buttons doesn't sit parallel with the board, its pins have been bent, so adjust them using needle-nose pliers and try again.

Having fitted the switches to the board, place the flat face of a ruler along the top of the buttons and check that they all line up. That done, carefully solder two diagonally opposite pins for each button without disturbing them, then test fit the board to the front panel on 6mm spacers to make sure the buttons are all correctly aligned. Adjust them as necessary, then solder the remaining pins.

Next, install the two 5mm LEDs. These are also inserted from the copper side, with the green LED (LED5) closest to the edge of the board and the yellow LED (LED4) nearest the centre. The tops of the LEDs must sit 11mm above the board, so that they will later protrude through the front panel by about 2mm.

In practice, this means mounting the LEDs 2mm proud of the board and this can be done by pushing them down onto a 2mm-thick cardboard spacer (slid between the leads) before soldering them. Make sure they are correctly oriented (ie, cathode (K) to the left).

The last part to install is the infrared receiver (IRD1). This must be orientated as shown in Fig.9, with its domed lens facing outwards and in line with the switch centres. The rear of its body should sit about 1mm above the PC board.

In practice, all you have to do is bend its leads down through 90° about 2mm from its body, then push it all the way down onto the board against a 1mm-thick cardboard spacer to set the height. It's then just a matter of checking that its lens lines up with the switches before soldering the leads.

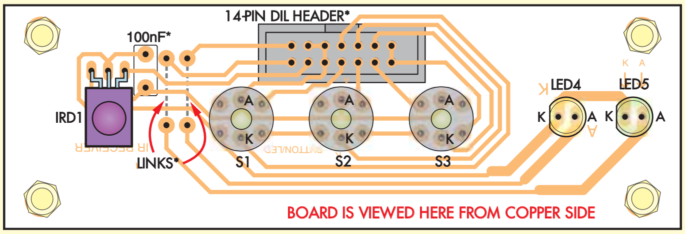
Power Supply Board

Our next task is the construction of the Power Supply Board. The component layout is shown in Fig.11. This board (coded 823), together with the three previous PC board, is available from the *EPE PCB Service* as part of a set.

Commence construction by installing the low-profile components first,

Table 3: Resistor Colour Codes – DAC Board

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	4	820Ω	grey red brown brown	grey red black black brown
❑	4	220Ω	red red brown brown	red red black black brown
❑	4	200Ω	red black brown brown	red black black black brown
❑	4	180Ω	brown grey brown brown	brown grey black black brown
❑	2	100Ω	brown black brown brown	brown black black black brown



*NOTE: IRD1, SWITCHES S1-S3 AND LEDS 4 & 5 MOUNT ON COPPER SIDE OF THE BOARD. THE 100nF CAPACITOR, DIL HEADER & WIRE LINKS ARE ON OTHER SIDE.

Fig.9: the Front Panel Switch Board assembly. Note that the infrared receiver (IRD1), switches and LEDs are mounted on the copper (track) side of the PC board. The header, links and 100nF capacitor go on the other side. Take care with the switch orientation (see text).

These photos show the completed Front Panel Switch Board. Be sure to mount the IDC header with the orientation shown (ie, notch towards the edge of the PC board).

starting with the single wire link, resistors and diodes. To aid heat dissipation, the two 5W resistors should be mounted about 2mm proud of the board surface.

Take care with the orientation of the electrolytic capacitors and be sure not to interchange regulators REG1 and REG2. Note also that they face in opposite directions! It's not necessary to fit heatsinks to either of these two regulators, although they were fitted to the supply in the prototype.

Not shown in Fig.11 is the wiring to the specified 15V-0V-15V 30VA or 20VA toroidal mains transformer. This will be covered next month. You can, if you wish, drive the supply board from a 15V AC plugpack.

We understand that Jaycar Electronics will be able to supply a kit (cat. KC-5418). This does not include the toroid transformer, (Jaycar MT-2086).

Installing REG3

Unlike REG1 and REG2, regulator REG3 mounts horizontally and *must* be fitted with a heatsink. Bend its leads down 90° about 5mm from its body and trial fit it in position to verify that the hole in the metal tab lines up with its hole in the board. Adjust as necessary, then slide a TO-220 heatsink between the regulator and the PC board after applying a thin smear of heatsink compound to the mating surfaces.

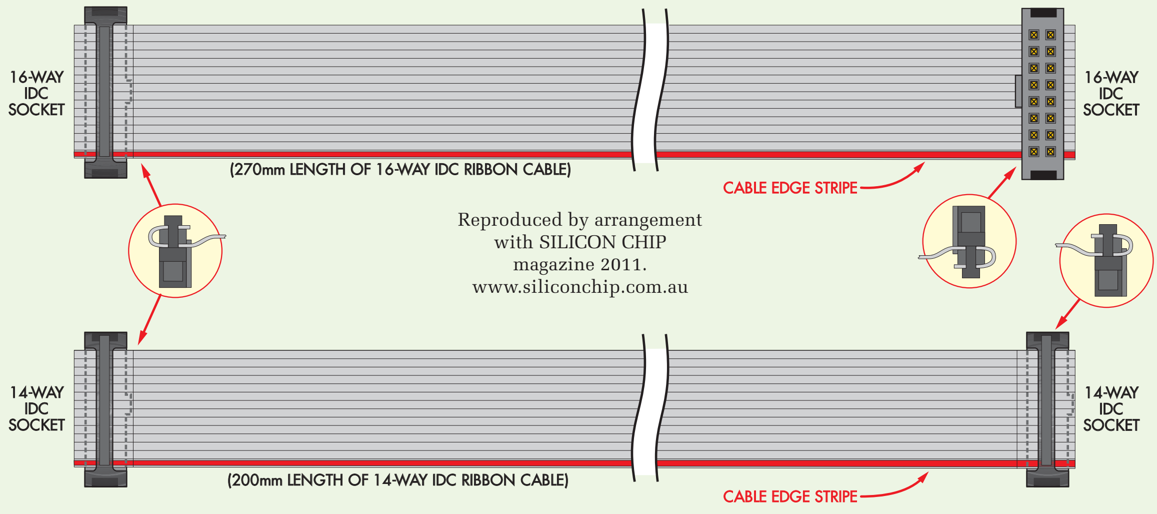
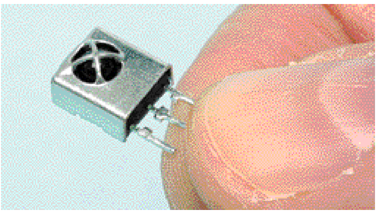


Fig.10: it's important to orientate the header sockets exactly as shown when making up the two IDC header cables. You must also leave about 15mm at each end so that it can be looped back and clamped with the locking bar.



A close-up view of the infrared receiver module (the Jaycar version doesn't have a metal shield). Bend its leads down at right angles before mounting it on the PC board.

Secure the assembly to the board using an M3 × 10mm screw, flat washer and nut. Don't solder the regulator's leads until after the screw has been tightened, otherwise the PC board tracks or the regulator package (or both) could be damaged.

Making the ribbon cables

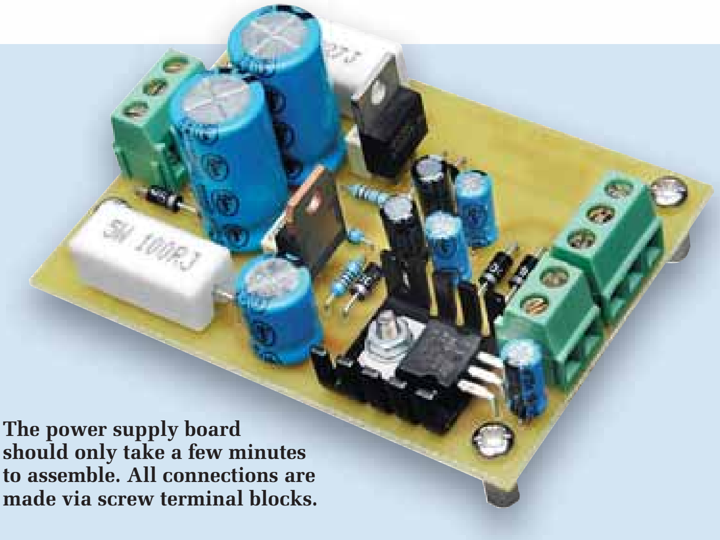
Now for the two IDC cable assemblies. Fig.10 shows the details.

Start with the 16-way cable. First, cut this cable to a length of 270mm, then clamp a 16-pin IDC header socket (rectangular locating tab facing inwards) to one end, with the red strip going to pin 1. You can do this by sandwiching the assembly together in a vice, or by using a crimping tool. Be sure to leave about 15mm free at this end so that it can be looped back and clamped with the locking bar.

That done, fit a 16-pin header socket to the other end. This header must go on the opposite side of the cable, with the red cable strip again going to pin 1. As before, its locating spigot should again face inwards.

Basically, it's just a matter of orienting the headers at each end exactly as shown in Fig.10. Note that pin 1 on the header sockets is indicated by a small triangle in the plastic moulding.

The 14-way cable is slightly different – see Fig.10. Begin by cutting the cable to 200mm and attaching a header socket to one end with its spigot facing inwards. That done, fit the second header socket to the other end of the cable on the same side. It should be oriented the same way as the first, with its locating spigot facing outwards.



The power supply board should only take a few minutes to assemble. All connections are made via screw terminal blocks.

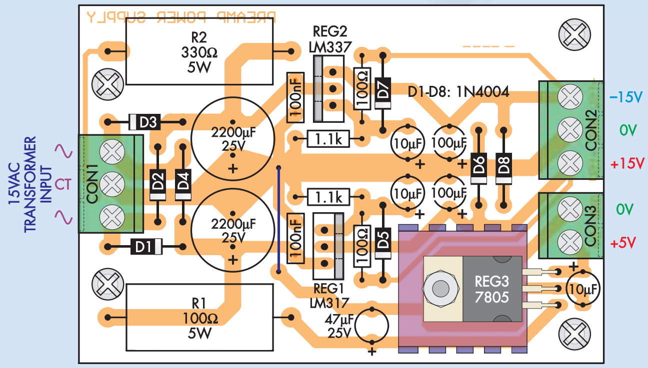


Fig.11: here's how to build the Power Supply Board. Don't get the 3-terminal regulators mixed up and note that REG3 is fitted with a heatsink.

Having completed the cables, it's vital to check that they have been properly terminated. If they are not crimped correctly, then some of the pins may be open circuit because the 'blades' in the header sockets haven't fully pierced the cable insulation.

The best way to check them is to connect the PC boards together and then use a multimeter to check for continuity between the corresponding header pins on each board. If you do find any open circuits, then that cable should be discarded and a new one made up.

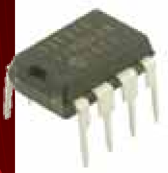
This procedure will also reveal if any of the header sockets has been incorrectly oriented.

That's it for this month. Next month, we'll show you how to assemble the modules into a steel case and get it all going. We'll also show you how to customise the remote control codes and the various software options.

Table 4: Resistor Colour Codes – Power Supply Board

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	2	1.1kΩ	brown brown red brown	brown brown black brown brown
❏	2	100Ω	brown black brown brown	brown black black black brown
❏	1	330Ω	orange orange brown brown	orange orange black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown

Integrated Circuits



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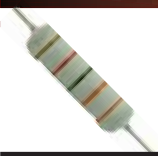

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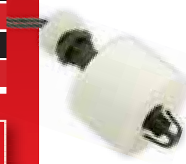

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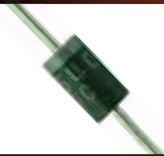

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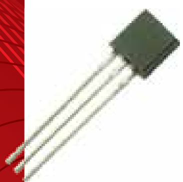

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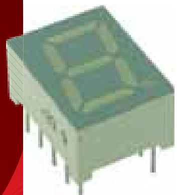

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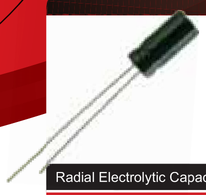

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Twin Engine SpeedMatch Indicator

By JOHN CLARKE

Avoid unnecessary noise and vibration in twin engine boats by using this Twin Engine SpeedMatch Indicator. It comprises a meter that is centred when both motors are running at the same speed. When the motors are not matched in revs, the meter shows which motor is running faster and by how much.

MOST power boats over eight metres long have two engines, typically in-line 4-stroke diesels or petrol V8s, each driving its own propellor via a shaft or stern drive. Normally both motors should run at exactly the same speed unless the boat is manoeuvring up to a jetty or mooring, in which case the propellers may run at differing speeds and direction.

All boat-owners know how important it is to have the motors running at exactly the same speed. If the motors don't run at the same speed, there can be excessive noise and vibration and the motors will be far less efficient as one prop tries to pull the boat harder and the other produces more drag.

At the same time, having the motors running at slightly different speeds means that you have to provide correction with the rudder to maintain a straight course and that causes further drag. In fact, a speed difference between motors of as little as 15rpm can cause lots of vibration that can radiate through the whole boat – most unpleasant.

Synchronisation

To explain further, with V8 motors a difference of 15rpm will cause a beat note of 1Hz. This is because V8s have four firing strokes per revolution, so 15rpm is equivalent to 60 pulses per minute or 1Hz. Apart from being most unpleasant to those on board, such low frequency vibration also causes lots of wear in the engines, gearboxes and shafts. So synchronisation of motors is highly desirable.

In fact, late model up-market boats often do have a facility for synchronisation. There are also electromechanical synchronisers available for older boats, although these can be difficult and expensive to fit.

So, most boat owners equalise the motor speeds as well as possible by watching the tacho readings and listening for the beat frequency. Trouble is, most boat tachos are not very accurate (typically ±3% or worse at mid-scale) and they can also be subject

to wavering readings. Furthermore, if you are driving the boat from the flybridge in bad weather, it can be very difficult to clearly hear the engine exhausts, meaning that it is even more difficult to listen for 'beat' notes.

And if your hearing is not the best (very common with older drivers), the difficulty is compounded.

Beat indicator

Clearly, an electronic beat indicator is required. In setting out to produce a suitable design, we thought about an indicator based on an LED bargraph. When it was centred, the motors would be in sync.

However, trying to see LEDs on a bright sunny day when driving on the flybridge is next to impossible, and that goes for almost any electronic indicator. That is why most boats tend to have conventional analogue meters – they are easy to see!

Hence, we decided to base our design on a good old-fashioned analogue meter movement. When the motors are running at the same speed, the meter will be centred and if not, it will show the difference at up to 200rpm (or whatever you decide to set). It is then easy to adjust the throttles so that the meter is centred.

The basic set-up of the Twin Engine SpeedMatch Indicator is shown in Fig.1. It compares the tachometer signals from each motor and the difference in RPM is shown on the panel meter. The panel meter needle is centred when the motor speeds are identical.

If the port (left) motor is running faster than the starboard (right) motor, then the needle will move left. Similarly, if the starboard motor is running faster, the needle will move to the right.

The meter shows only the difference in RPM and it does not matter if the engines are running at full speed or at idle.

Signal sensor

The tacho signals will usually be a low-voltage signal from a Hall effect sensor or reluctor, or they can be obtained from the ignition coils or from another source, such as a low-voltage tachometer signal from a sensor. Where these are not available, such as in a diesel motor, a signal from the alternator can be used instead.

Fig.2 shows how the two tacho signals are compared. Each tacho signal is fed to a frequency-to-voltage converter

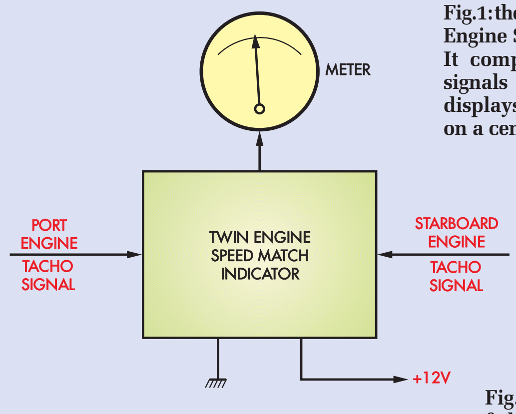


Fig.1: the basic set-up of the Twin Engine SpeedMatch Indicator. It compares the tachometer signals from each motor and displays the difference in RPM on a centre-zero meter

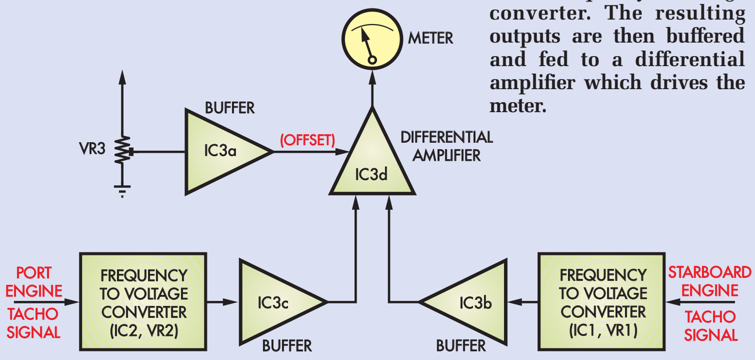


Fig.2: each tacho signal is fed to a frequency-to-voltage converter. The resulting outputs are then buffered and fed to a differential amplifier which drives the meter.

(IC1 and IC2). The resulting voltage outputs are then buffered (IC3b and IC3c) and compared in a differential amplifier, IC3d. This is offset using trimpot VR3 and then buffered by IC3a.

The offset voltage centres the meter (ie, to half scale) when the tachometer signals are the same frequency.

Circuit description

The full circuit diagram is shown in Fig.3. It comprises two LM2917 frequency-to-voltage converters (IC1 and IC2), a quad op amp package (IC3), plus associated resistors, capacitors and diodes.

Each tacho signal is applied to a filter network consisting of a 10kΩ resistor and a 22nF capacitor. This is followed by a 22V Zener diode and a 20kΩ resistor to ground (0V). This filtered signal is fed to the non-inverting input of a Schmitt trigger at pin 1 of the LM2917 (IC1 and IC2).

The Schmitt trigger threshold (pin 11) is set at about +0.55V by the 10kΩ and 1kΩ voltage divider connected across the 6V supply. The output from the Schmitt trigger drives an internal charge pump which involves capacitors C1 and C2 (see Fig.4). Capacitor C2 is discharged using the series 100kΩ resistor and a 1MΩ trimpot (VR1 and VR2 for IC1 and IC2, respectively).

Frequency-to-voltage converter

The LM2917 is a special-purpose chip which has a number of refinements to ensure that the frequency-to-voltage conversion is linear. First, capacitor C1 is charged via a current source to a voltage that is ¾ the main supply to the IC. This charge current is duplicated (using a current mirror) for capacitor C2.

During discharge, C1 is discharged to ¼ the main supply at a constant

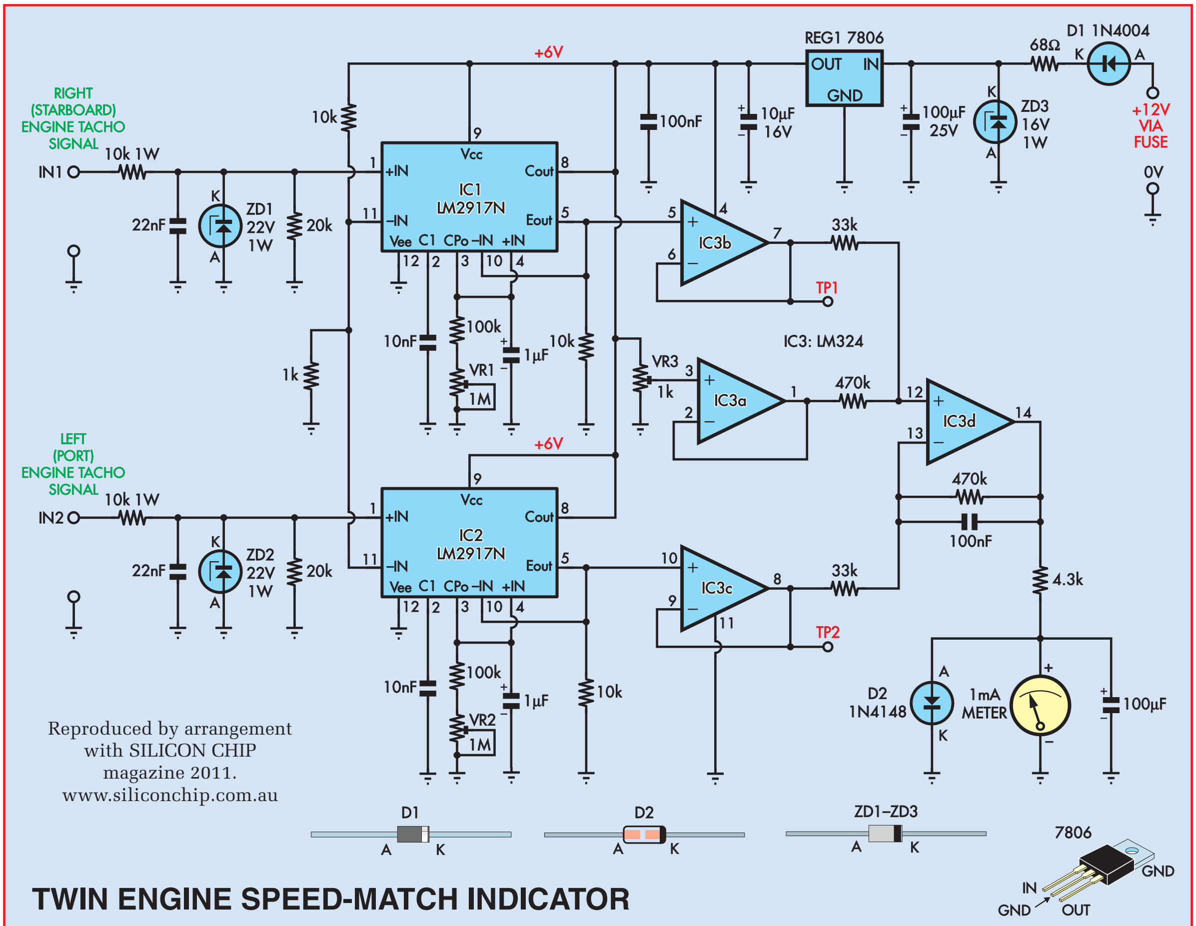
Specifications

Power consumption: 12V at 20mA

Tacho input range: 0 to 6000rpm

Display range: typically set to ±200rpm

Tacho input voltage: 0.83V to 350V AC



TWIN ENGINE SPEED-MATCH INDICATOR

Fig.3: the full circuit for the Twin Engine SpeedMatch Indicator. IC1 and IC2 (LM2917N) are the frequency-to-voltage converters, op amps IC3b and IC3c are the buffer stages and IC3d is the differential amplifier. Trimpot VR3 and IC3a provide an offset voltage for IC3d to centre the meter.

current. The specified upper and lower voltage thresholds ensure that the current source and discharge current circuitry operate within their designed voltage range.

In addition, charging and discharging is at a rate that is twice the frequency of the tachometer input. This doubling of input frequency reduces the ripple across C2. Fig.4 shows the internal schematic of the LM2917.

The charge pump voltage at pin 3 is applied to the non-inverting input of the amplifier internal to the LM2917. The inverting input to this amplifier at pin 10 is connected to the emitter output at pin 5 and this sets the amplifier as a unity-gain buffer. A 10kΩ pull-down resistor provides the emitter load.

Op amps IC3b and IC3c are connected as unity-gain amplifiers to buffer the pin 5 outputs of IC1 and IC2. The buffered outputs are then fed to op amp IC3d which functions as the differential amplifier.

IC3d works as follows: the output from IC3c is amplified with a gain of –14, as determined by the 470kΩ resistor between pins 13 and 14 and the 33kΩ input resistor. The output from IC3b is first attenuated by the 33kΩ and 470kΩ voltage divider at pin 12 of IC3d (non-inverting input). The signal at pin 12 is therefore only 14/15 of the output from IC3b.

The overall signal gain at pin 12 is 1+ (470kΩ/33kΩ) or 15. Therefore, the overall gain for the signal from IC3b is 15 × 14/15 or 14, ie, the same gain as for the signal from IC3c except that it is positive (instead of negative).

Note: we are using the LM324 right on the limits of its specifications in this circuit. This is because the LM324 op amp only has a 50µA sink current for output voltages less than +0.5V. This is why the resistor values in the circuit are relatively high.

However, considering the DC outputs from the LM2917 frequency-to-voltage converters are generally above 0.5V when the engines are idling and more at higher RPMs, this is not really a problem for this application.

If you are using this circuit for a different purpose and require a better result, especially at low outputs from the frequency-to-voltage converters, we would recommend using an LMC6484AIN CMOS rail-to-rail quad op amp in place of the LM324.

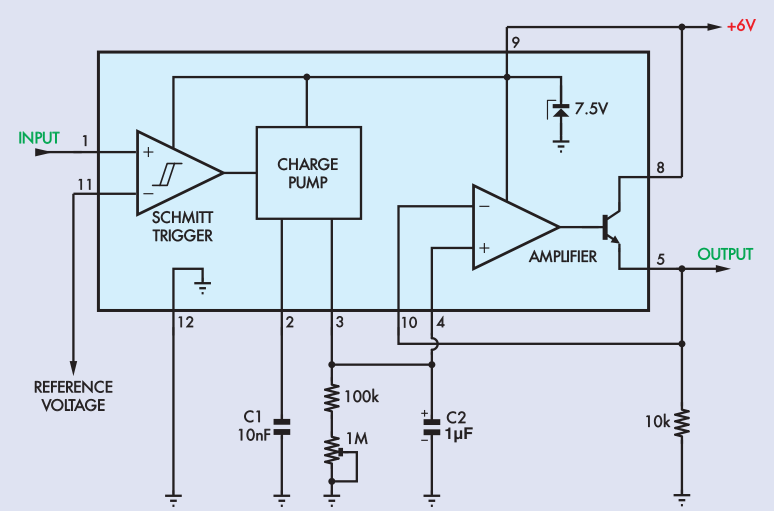


Fig.4: the LM2917N frequency-to-voltage converter consists of a Schmitt trigger, a charge pump and an amplifier wired here as a unity-gain buffer.

Parts List

1 PC board, code 824, available from the *EPE PCB Service*, size105mm × 63mm
1 1mA MU45 moving coil meter (Jaycar QP-5010) – see text
4 2-way PC-mount screw terminal blocks (5.08mm pin spacing)
3 14-pin IC sockets
2 solder eyelet lugs
2 PC stakes
1 75mm length of 0.7mm tinned copper wire (for links)
Silicone sealant, hook-up wire

Semiconductors
2 LM2917N frequency-to-voltage converters (IC1,IC2)
1 LM324 quad op amp (IC3)
1 7806 6V regulator (REG1)
2 22V 1W Zener diodes (ZD1, ZD2)
1 16V 1W Zener diode (ZD3)
1 1N4004 1A diode (D1)
1 1N4148 signal diode (D2)

Capacitors
2 100µF 16V electrolytic
1 10µF 16V electrolytic
2 1µF 16V electrolytic
2 100nF MKT polyester
2 22nF MKT polyester
2 10nF MKT polyester

Resistors (0.25W 1%)

2 470kΩ	2 10kΩ 1W
2 100kΩ	1 4.3kΩ
2 33kΩ	1 1kΩ
2 20kΩ	1 68Ω
3 10kΩ	

2 1MΩ multiturn top-adjust trimpots (VR1, VR2)
1 1kΩ multiturn top-adjust trimpot (VR3)

Meter offset

Op amp IC3a buffers the voltage from VR3 and provides the offset voltage for IC3d. IC3d is offset so the meter sits at half-scale (ie, centred) when there is no difference between the two input frequencies. For this half-scale condition for the 1mA meter, 500µA needs to flow, and so VR3 is set for this condition, ie, close to +2.25V.

The meter movement is damped with a 100µF capacitor across it. Normal full scale deflection of the meter will occur with +4.5V from IC3d. Note that while a gross difference in engine speeds can result in more than full scale deflection of the meter, the resultant overload is quite modest since IC3d's output can only go slightly above +4.5V with a 6V supply.

We have also included diode D2 across the meter. If a circuit fault applies excessive voltage to the meter, the diode will conduct at about 0.6V restricting the meter current to 0.6V/200Ω or 3mA.

Power for the circuit comes from the boat's 12V battery (ie, one of the engine batteries) via a fuse (ie, a switched accessory supply rail), and is applied through diode D1 for reverse polarity protection. The 68Ω resistor and 16V Zener ZD3 protect against transient voltages, while a 100µF capacitor provides supply decoupling. Regulator REG1 then provides the 6V supply and its output is bypassed with a 10µF capacitor. A 100nF capacitor is also connected across the supply near IC1.

Construction

The Twin Engine SpeedMatch Indicator is constructed on a PC board, code 824, measuring 105mm × 63mm. This board is available from the *EPE PCB Service*. The component layout for the PC board is shown in Fig.5.

The PCB can clip into the integral mounting clips within a UB3-size plastic case if required. Alternatively, four corner mounting points are provided for mounting in a different box or inside the dashboard of the boat. Note that if you have two helm positions in the boat, you will need two SpeedMatch Indicators.

Begin construction by checking the PC board for breaks in the copper tracks or shorts between tracks and pads. Repair if necessary. Check that the hole sizes are correct for each component to fit neatly. The screw terminal holes are 1.25mm in diameter compared to the 0.9mm holes for the IC, resistors and diodes. The four corner mounting holes should be 3mm in diameter.

Begin by inserting the wire links, PC pins, diodes and resistors. We used 0Ω resistors in place of wire links, but the latter could also be used. The diodes must be mounted with the orientation as shown. When inserting the resistors, use the resistor colour code table to help in reading the resistor values. A digital multimeter should also be used to check each value.

Sockets are used for all three ICs, and these must all be oriented in the same direction, with the notches as shown in Fig.5. Once they're in, fit the 3-terminal regulator (REG1) and the three trimpots, all of which mount with the screw adjustment oriented as shown.

The terminal blocks consist of two 2-way sections which are locked together before the are inserted and soldered into the PC board.

The capacitors can be mounted next, ensuring that the electrolytics are oriented correctly. Finally, the three ICs can be mounted in their sockets, again ensuring each is oriented correctly.

Testing

The Twin Engine SpeedMatch Indicator requires a 12V DC supply or

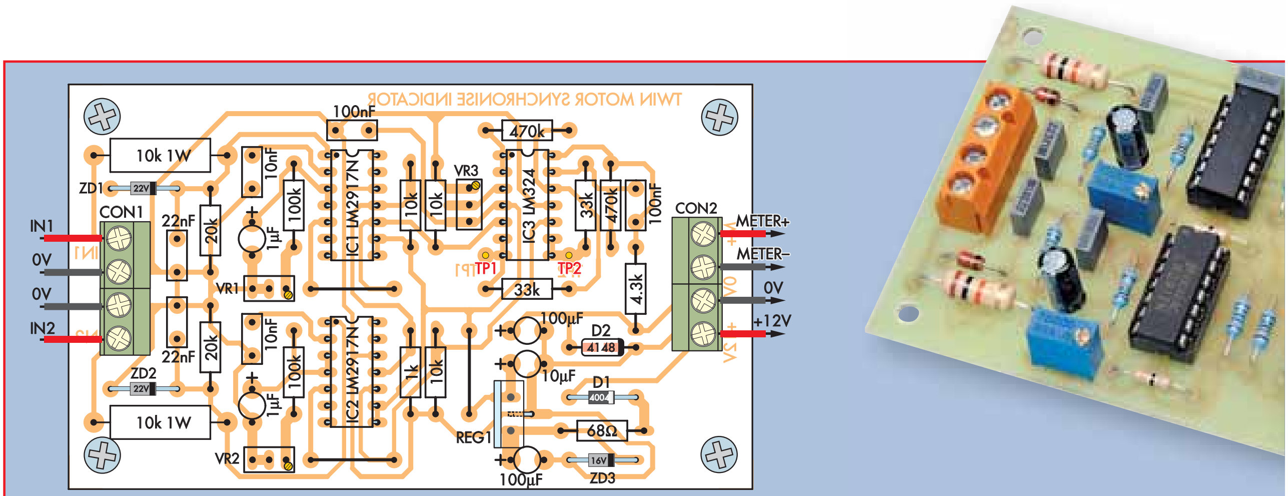


Fig.5: install the parts on the PC board as shown on this wiring diagram and the photo at right. In particular, make sure that all polarised parts are correctly installed and that trimpots VR1-VR3 have their screw adjustments positioned as shown.

anything from 8V to 16V DC at about 20mA. Apply power and check that there is +6V between pin 9 and pin 12 of both IC1 and IC2, and between pin 4 and pin 11 of IC3.

If there is no voltage, check for +6V at the output of REG1. Note that +6V is a nominal value and could range from +5.85V to +6.15V, depending on the particular regulator. If there is no voltage from the regulator, D1 may be reversed or there may be a short circuit between the +6V rail and 0V on the PC board.

Marine meter movement

The meter shown in this article is a standard 1mA FSD (full scale deflection) analogue movement. However, depending on your application, this may or may not be suitable. For example, it may be OK if used on the helm dashboard inside the cabin. However, it almost certainly won't be suitable if used on the helm dashboard on the flybridge, where it will be exposed to the elements.

Most boat owners may want the meter to match the other meters on their dashboard and this approach will no doubt be far more expensive – as is everything associated with boats. On the other hand, taking this approach will mean that the meter will probably include illumination, will be sealed against moisture ingress and condensation and incorporate a lens (eg, in VDO gauges).

If you are going to use a matching meter, it will probably need to be adapted from a voltmeter. In that case, you will need to pull the meter apart to change the scale. You will also need to remove the internal series resistor (voltage multiplier).

For the purpose of this article, we made up a replacement scale for the specified 1mA meter movement. If you use this particular meter, you can change the scale by carefully prising the plastic cover off the meter, undoing the two securing screws for the original 1mA scale and then attaching the replacement panel.

Fig.6 shows our replacement scale, which has maximum readings of ±200rpm, or rather PORT +200 0 STBD +200. Note that this is a relative indication only and *cannot* be relied on as having great accuracy. All analogue meter movements have their best accuracy at full-scale deflection of the meter and minimum accuracy at close to zero deflection.

In fact, since the SpeedMatch Indicator will be set up by you, it will be quite accurate for the centre speed match indication.

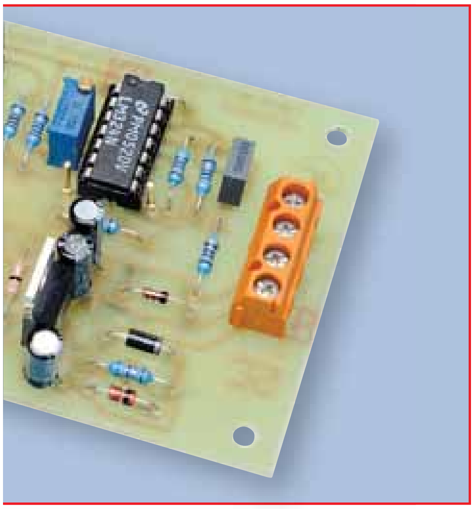
Setting Up

Connect the unit to the meter's M+ and M– terminals using leads terminated in solder eyelets. These eyelets are sandwiched between the nuts supplied with the meter. Ensure the meter polarity is correct. That done, apply power to the PC board and adjust trimpot VR3 so that the meter is centred.

Further setting up requires either a signal generator that can produce at least 1V output or by connecting the unit to the boat motor itself.

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	2	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❏	2	100kΩ	brown black yellow brown	brown black black orange brown
❏	2	33kΩ	orange orange orange brown	orange orange black red brown
❏	2	20kΩ	red black orange brown	red black black red brown
❏	3	10kΩ	brown black orange brown	brown black black red brown
❏	2	10kΩ	brown black orange brown	NA
❏	1	4.3kΩ	yellow orange red brown	yellow orange black brown brown
❏	1	1kΩ	brown black red brown	brown black black brown brown
❏	1	68Ω	blue grey black brown	blue grey black gold brown



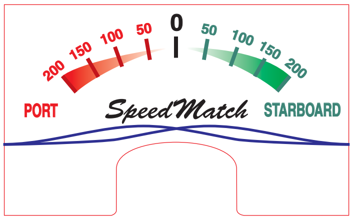


Fig.6: this full-size meter scale can be cut out or colour photocopied

Tachometer signal

As mentioned earlier, the inputs for the Twin Engine SpeedMatch Indicator can come from the ignition coil or from low-voltage tachometer signals. Where these are not available, such as in a diesel motor, a signal from a separate sensor or the AC from the alternator can be used instead. The Twin Engine SpeedMatch Indicator will operate without any changes using either the ignition coil or low-voltage signal.

If the alternator has to be used, then this may provide a higher frequency than from the other tachometer sources. The signal from the alternator is an AC signal and may be marked as AC, AUX, S, R or TACH.

An idea of how many pulses from the alternator per engine rotation can be gauged by measuring the diameter of the crankshaft pulley and dividing this by the alternator pulley diameter. The number of poles in the alternator is multiplied by this pulley ratio. The number of poles is usually 4, 6, 8, 10 or 12.

The Twin Engine SpeedMatch Indicator was designed for between two and four pulses per engine rotation. If the alternator signal is higher than this, then the 10nF capacitors at pin 2 of IC1 and IC2 will need changing to a different value. The 10nF value is reduced by the ratio of 3/number of alternator pulses per engine revolution. So, if the alternator produces 36 pulses per engine revolution, then the capacitor will need to be 10nF × 3/36 or 820pF, using the nearest capacitor value.

A separate tachometer sensor may also deliver a higher number of pulses per revolution. Again, the 10nF value needs to be reduced by the ratio of 3/number of sensor pulses per engine revolution. In addition, for this sensor, there may be two leads – one for the signal and one at 0V. The 0V connection is provided on the PC board for this purpose if it is needed.

Now connect the tachometer signal from one motor to both IN1 and IN2. Connect a digital multimeter, set to a DC volts range, between test-point TP1 and 0V on the PC board. With the motor running, adjust trimpot VR1 for a reading of 0.8V per 1000rpm, eg, 1.6V at 2000rpm. This sets the meter scale to ±200rpm.

If the voltage cannot be set within the range of the trimpot adjustment, then the 10nF capacitor at pin 2 will need changing. If the voltage is too high, use a lower value capacitor and if the voltage is too low, use a larger value. As a guide, reducing the capacitor value by a factor of two will reduce the voltage by the same amount.

Having adjusted VR1 so that 'test point' TP1 is at 1.6V at 2000rpm, set trimpot VR2 so that the 1mA meter is centred. That is all the setting up requires.

Testing

Now connect the IN1 and IN2 inputs to the separate motor tachometer signals and test the operation. Note that it is quite possible that you will find that when the SpeedMatch is indicating that the motors are synchronised, the tacho readings may not be exactly the same.

This is to be expected with most analogue tachometers, since they are not particularly accurate, especially those with 270° movements (ie, most tachos). For example, a tachometer with a mid-scale accuracy of ±4% will have an error in the range of ±100rpm at an engine speed of 2500rpm. So, it is quite possible that the port engine tacho might indicate 2400rpm, while the starboard engine tacho indicates 2600rpm when the engines are actually doing the same speed.

At low engine speeds, the tachos may be more inaccurate. For example, at 1000rpm, the accuracy may only be ±10%, which means, again, that the readings can be off by ±100rpm.

Why are analogue tachos so bad? It is because their basic accuracy of, say, ±2% only applies at full deflection. So, if the tacho reads to 6000rpm, its reading is actually 6000rpm, ±120rpm. It does not get any better at lower readings and in fact, the linearity at small deflections for all analogue meters is generally not good.

Unfortunately, where the tacho signal is derived from the alternator, as in the case of some diesels, the tacho signal itself can be inaccurate because of variable slip in the drive belt. The only cure for this is to install a Hall effect sensor, and an accompanying magnet on the harmonic balancer, flywheel or the prop shaft.

Installation

The Twin Engine SpeedMatch Indicator is presented as a bare PC board and separate meter. For installation, we recommend you seal the meter top cover to the body with silicone sealant. The meter can be mounted in the boat dashboard using a suitable bracket. Standard boat gauges tend to fit into a $3^3/_8$-inch (85.73mm) diameter hole and the meter would need to be mounted onto a metal plate.

The PC board can mount inside the boat dashboard. If you want to mount it in a box, it will fit into a UB3 box measuring 130mm × 68mm × 44mm. **The +12V supply connection should be run to a FUSED accessory supply line that's switched by the ignition, while the wiring to the ignition coil should use mains-rated (230V AC) cable.**

For moisture protection use cable glands for wire entry and seal the box with silicone sealant after calibration.

24V operation

Some boats may have 24V batteries. For 24V operation, the 16V Zener diode ZD3 should be changed to 33V 1W and the 100µF 16V capacitor at the input to the 3-terminal regulator (REG1) should be increased in voltage rating to 35V or 50V. In addition, REG1 should be fitted with a small heatsink. **Wiring to the ignition coil should use mains-rated (230V AC) cable.** *EPE*

Win a Microchip Bluetooth Evaluation Kit

EVERYDAY PRACTICAL ELECTRONICS is offering you the chance to win a Microchip Bluetooth Evaluation Kit (part # DM183036). The kit provides an easy, cost-effective and flexible add-on for embedded evaluation and development using many 16/32-bit PIC microcontrollers or dsPIC digital signal controllers (DSCs), using existing Microchip development tools.

The kit includes the Microchip Bluetooth PICtail Plus daughter-board, with the 16-bit USB PIC24FJ256GB110 and 32-bit CAN/USB PIC32MX795F512L microcontroller plug-in modules, both of which are pre-programmed with CandleDragon's dotstack Bluetooth demonstration stack and SPP profile. This kit is designed for use with Microchip's existing Explorer 16 Development Board (DM240001), which is included as part of the competition prize and worth $129.99 (£82.00).

Current Bluetooth wireless modules are costly and inflexible because they force developers to use a predetermined baseband radio and microcontroller. The new Microchip and CandleDragon Bluetooth solution enables designers to pair a wide range of radio ICs for Bluetooth connectivity with many of Microchip's 16/32-bit PIC microcontrollers or dsPIC DSCs. Additionally, CandleDragon's dotstack is Bluetooth SIG compliant and supports multiple profiles in a single microcontroller, including SPP, HFP and HID, with more profiles planned for Microchip MCUs in the near future.

HOW TO ENTER

For your chance to win a Microchip Bluetooth Evaluation Kit and Explorer 16 Development Board, visit: **www.microchip-comps.com/epe-bt**

CLOSING DATE

The closing date for this offer is 30 November 2011

White space and taboo channels

TechnoTalk

Mark Nelson

Since the early 1970s, people have exploited gaps between stations in the FM broadcast band – illegally. But now the pirates will have to weigh anchor, as communications regulator OFCOM is suggesting these and other surplus slivers of spectrum could be used for Internet access. This is all part of a global 'white space' initiative to make better use of the airwaves. Mark puts this move in context.

WHITE space is nothing more than a handy term for unoccupied radio channels, but for protagonists of new technology it's an exciting prospect for enabling wider and cheaper access to the Internet.

The idea is that white space applications would work in a similar way to WiFi, which uses wireless at hotspot locations to enable users of wireless devices to hook up to the net. White space connectivity operates in a more intelligent manner with regard to location and device characteristics, using geolocation database lookup to avoid interference with other devices operating in the vicinity.

Making space

The transition from analogue to digital broadcasting (already underway on the UHF television band in Britain) and a similar process for FM radio will release spectrum for other users. Just under a year ago, OFCOM launched a consultation on the technology implications and how new low-cost connectivity systems can be made available to consumers, using white spaces between digital TV channels.

It is now realised that the same access technology could exploit white spaces in the FM radio band, which OFCOM chief executive Ed Richards confirmed on 6 July. White space devices could use frequencies freed up in the VHF FM band to deliver innovative applications such as wirefree broadband in very sparsely populated areas.

The communications watchdog body anticipates that all large-scale radio stations will migrate to digital, eventually ceasing to broadcast on analogue FM radio. Smaller stations are expected to remain on FM. This could release up to 50 per cent of the capacity currently used to deliver FM radio services and has raised questions as to what this capacity will be used for.

'Our first principle has to be that any future use of the FM band is an efficient use of the radio spectrum,' said Mr Richards. 'There must be certainty for smaller and community stations, that do not move across to DAB. These will continue to play their important role, and FM is an appropriate technology for the scale at which they operate.'

Why white space?

White space has been dubbed 'WiFi on steroids'. At the frequencies released by FM radio and UHF television, signals travel much further and more easily through walls than the microwave channels used for WiFi. Experts quote ranges as far as 10km, compared with about 250m for normal WiFi hotspots.

This would reduce the cost of rolling out wireless broadband and avoid digging up roads, trees and pavements to lay cables. And because the radio spectrum would be licence-free, service providers would not have to spend millions on access licences.

A standard has already been devised that permits both M2M communications and local broadband delivery, using adaptive frequency hopping between 8MHz channels and a variety of modulation schemes. Data rates can vary between 10kbit/s to 16Mbit/s, delivered at distances up to 10km from the base station.

Pirates go home?

Ed Richards explained that the white space solution would safeguard the interests of the radio industry by making it less likely that it was back-filled with new commercial and pirate radio stations. He stated: 'White space devices offer a creative solution that would not only use spectrum to its full capacity, but would also work alongside existing smaller FM radio stations. This could be done without causing interference and without any commercial conflict..'

Nice sentiments, although the FM pirates are a tenacious bunch and have yielded no ground at all in three decades. On this tack, the OFCOM viewpoint looks rather like a triumph of optimism over experience. That apart, white space radio clearly has a lot going for it, and could easily become an all-pervasive technology, judging by industry support.

Reality check

Trials are already in progress, conducted by Microsoft with backing from a consortium of big-hitters such as BT, the BBC, Sky Television and Nokia. One of the locations is Cambridge, where the consortium will test streaming high-quality video and audio content from the BBC and BSkyB to a range of mobile devices at hotspots, including pubs, other leisure venues, and commercial and residential premises in and around the city.

Cambridge is an ideal testing ground, with a dense mixture of buildings, including the historic stone buildings of its colleges, enabling a comparison of the penetration of white space signals with microwave WiFi networks. And although Cambridge itself has good broadband access, some neighbouring villages suffer poor broadband service, allowing the enhanced range of white space communications to be demonstrated.

Meanwhile, on the Isle of Bute, located off the west coast of Scotland, the Openreach (retail) division of British Telecom has begun testing wireless broadband using white space technology. It is particularly keen to help out householders who have no access to broadband at all, or who are only able to connect to speeds of lower than 2Mbit/s because of the distance between their property and the nearest telephone exchange. Early indications have already returned some 'very promising' results, says BT, which is receiving funding from the government's Technology Strategy Board.

Wait, there's more

Wirefree broadband is not the only application for white space networks, however. It is also being promoted for machine-to-machine (M2M) communications. A key application is smart metering for gas, water and electricity, something that has government support. And this is only one of some 70 applications that have been identified by Neul, the high-tech company supporting the White Space Consortium's trials in Cambridge. The system would also be ideal for road toll collection, asset tracking and electronic point-of-sale applications, together with home automation, home-based healthcare and diagnostic monitoring.

The technology to enable this is the easy part, as the trials are already demonstrating. What is needed now is the software 'glue' that binds the various elements, enabling them to deliver the coordinated applications that users want.

Open-USB-IO: a universal I/O solution

This hardware I/O board will let you drive a host of digital and analogue I/O (input/outputs) via the USB interface on your laptop or desktop computer.
Based on an Atmel Atmega32 microprocessor and not much else, it works on Windows, Linux and Macs.

By
Dr Pj Radcliffe
Senior Lecturer, School of Electrical & Computer Engineering, RMIT University

IN THE days of Windows 98 and DOS, you could directly write to the hardware ports on your computer, typically to the parallel printer port and serial port. This was great for hobbyists and many good projects were built around programs which directly accessed hardware.

A very useful logic analyser was built that worked at 1MHz just by reading the digital inputs of the parallel port. I also controlled a bank of relays with C code, writing to the parallel port.

Then came Windows XP, a great improvement over Windows 98, except that it blocked direct access to hardware ports. There was a quick and dirty fix called **giveio.sys**, but it wasn't always reliable.

Next, parallel and serial ports started to disappear from laptops and even desktop PCs. Finally, along came Window Vista, which has completely blocked I/O access. Thus, hobbyists have been deprived of a powerful, simple, and cheap way to access hardware from program code.

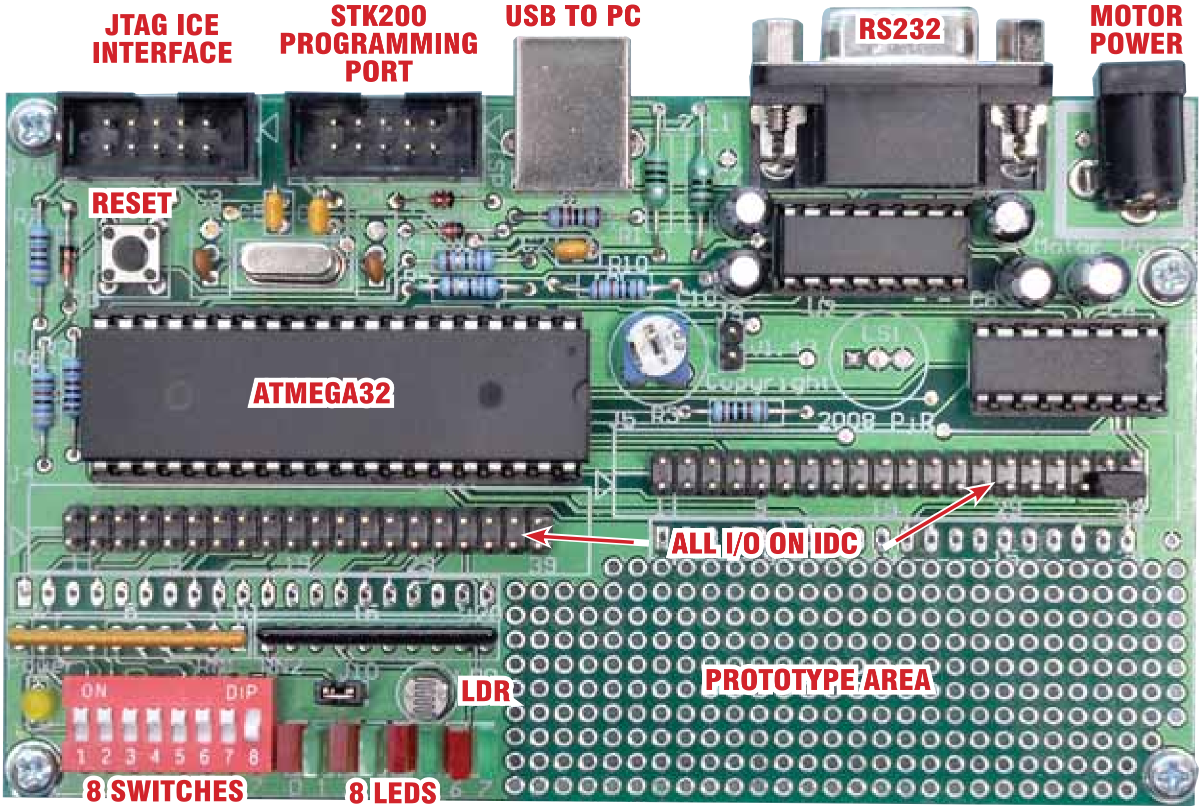
This inability to easily control hardware is not just a problem for hobbyists. At RMIT University where I lecture, we had the same problem with our labs and major projects.

In the computer and networks degree, students need to become familiar with hardware, software, networks and the interaction between hardware and software (optional in electrical and electronic and communications degrees).

In our quest to find ways for software to control hardware we found several USB boards that allowed digital input and output (I/O), but they were either expensive, didn't do all we wanted, didn't work on Windows *and* Linux *and* Macs, or needed special drivers to be installed.

We drew up the specifications for our ideal hardware I/O board:

- Cheap.
- Lots of digital I/O, analogue inputs and PWM outputs.
- Basic I/O: LEDs, a light-dependent resistor (LDR) and a trimpot for simple analogue work.
- An RS-232 serial data port, not used for any system function such as programming.
- The ability to drive DC motors or stepper motors (at least 500mA and 50V each).
- USB-driven, with no special drivers for Windows, Linux and Mac.
- Hardware I/O can be controlled from the PC via a GUI, command line or program code.
- Some prototyping area.
- Interface with simple hardware using 'easy-hooks', or complex hardware with a cable.
- All ICs in sockets, to allow easy repair if they are damaged.
- Users must be able to download their own code into a powerful microprocessor. Hardware can thus be controlled direct from the microprocessor with the USB just providing power.



Reproduced here significantly larger-than-life for clarity (it's actually 125mm wide), this is the Open-USB-I/O Board showing key interfaces.

- The whole thing should be Open Source and GPL for both software and hardware. This makes it easy for anyone to modify and extend the hardware or software, but they must release these changes back into the public domain. It also keeps the price down as no one manufacturer can have a monopoly on the board.

The result is the Open-USB-I/O board. Let's look at its key features and then see how to drive it.

What's on the Open-USB-I/O

The compact PC board packs a lot of features. Its heart is an Atmel ATMEGA32 microprocessor with 32KB of code memory, 1KB of EEPROM and 2KB of RAM. You can do a lot with 32KB of code memory!

It also has three timers, four PWM (pulse-width modulation) lines, eight A-D converter ports with 10-bit accuracy, serial data ports, digital I/O ports and much more.

Open-USB-I/O makes many of these available to the user, but a few must be kept to drive the interfaces, such as the USB and the programming port.

The board has eight LEDs and eight switches, which can also be used as eight digital inputs and eight digital outputs. In fact, these 16 lines can be used as any combination of inputs and outputs by reprogramming the data direction registers in the microprocessor.

Above the LED array there is an LDR (light-dependent resistor) which is read via one of the analogue inputs on the microprocessor. The LDR can sense the output of nearby LEDs which gives interesting possibilities, including an optical oscillator.

The trimpot in the middle of the board is connected to another analogue port and provides a convenient variable analogue input. Near the trimpot is a space where the user can add an additional 2-pin device, such as a buzzer.

Circuit description

The full circuit of the Open-USB-I/O board is shown in Fig.1. Only three IC packages are used: IC1 is the Atmel Atmega32 microprocessor; IC2 is the MAX232ACPE RS232 interface chip and IC3 is the ULN2003A Darlington array.

The top left shows the USB interface where the Zener diodes ZD1 and ZD2 act as voltage limiters, while the 68Ω resistors present the correct load to the PC USB port. The USB lines carry both DC power and high frequency data signals. Inductor L1 and the associated capacitors filter out noise to provide the DC rail, V_{CC}.

On a desktop computer, the USB port can supply up to 500mA, but laptops can provide rather less. The V_{CC} supply is clean enough for digital circuits, but has too much noise for analogue circuitry, so the combination of inductor L2 and the 100nF capacitor gives extra filtering to provide the AV_{CC} rail, which is used for all the analogue circuits in IC1.

The USB data interface is handled by firmware on the ATMEGA32 (IC1), which uses interrupt PD2 and pin PD7 to receive or drive signals to the USB line.

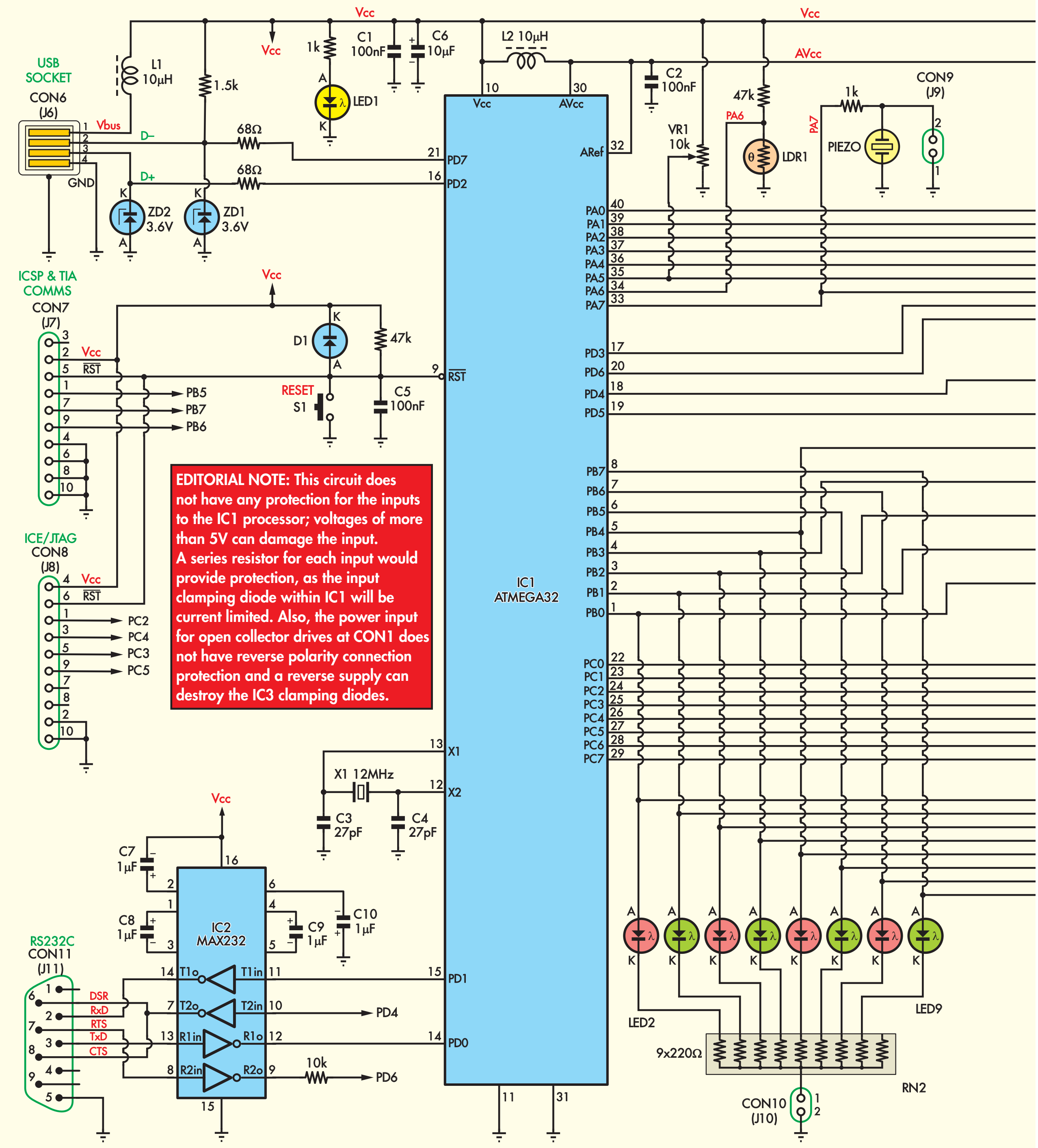
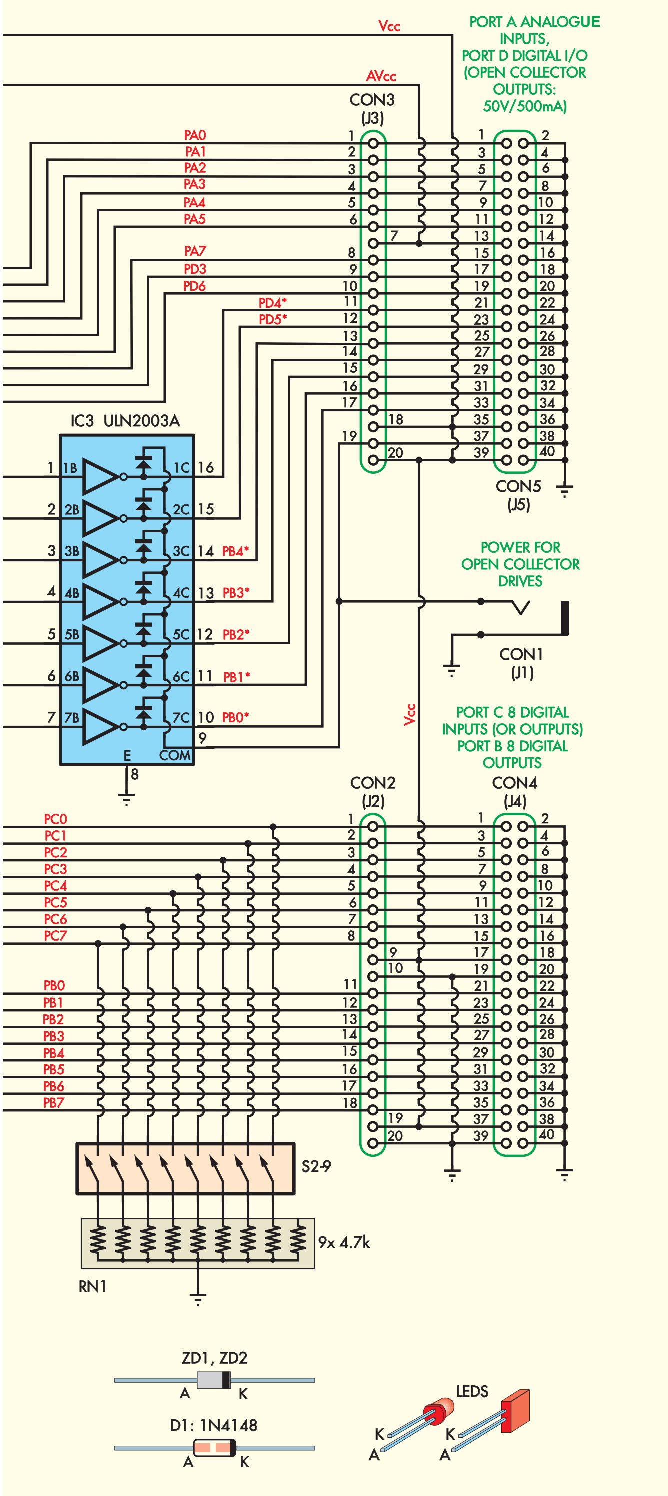


Fig.1: the circuit diagram for the Open USB I/O module shows it is primarily based on a programmed ATMEGA32, along with several input/output devices and LED indicators. The various input/output and power connectors are labelled here as CON1, CON2, etc, as is our normal practice. However, on the PC board overlay and in the text of this article they are labelled J1, J2 etc, so we have shown both to avoid any confusion.



OPEN USB I/O MODULE

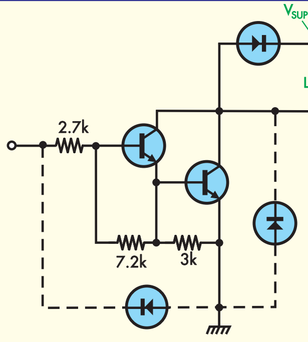


Fig.2: the internal circuit of one ULN2003 driver. The diode connected to V_{SUPPLY} stops inductive spikes from destroying the chip when a load is turned off.

The bottom right of the circuit has S2 to S9, a bank of eight switches which can be read by the microprocessor (IC1). The microprocessor provides internal 100kΩ pull-up resistors on each port C pin. These set each port C pin to logic high when the associated switch is open, and logic low then the switch is closed, bringing the external 4.7kΩ pull-down resistor (resistor array RN1) into play.

These inputs are available on the J4 connector (and the J2 holes below the connector). Any external output capable of driving the 4.7kΩ resistor could be connected here and be read by the microprocessor. If all the switches were set to off, the external input would only have to drive the 100kΩ pull-up resistor.

Port B of the microprocessor drives eight LEDs (LED2 to LED 9) through a 220Ω resistor array (RN2), and then via link J10 to 0V. If the link is removed the LEDs will not light. This can be useful if port B pins on connector J5 are intended to drive external devices.

Alternatively, the LEDs may be left connected when driving external circuitry, as the ATMEGA32 outputs are capable of driving 20mA and the LEDs only take around 12mA, thus leaving spare drive for external devices.

The ATMEGA32 should not drive more than 200mA for the entire chip as an absolute maximum, but given that the

Controlling Open-USB-I/O from the command line

```
[user]$ ousb io PORTB 85
 PORTB = 85
[user]$ ousb io PORTB 0xff
 PORTB = 255
[user]$ ousb io PINC
 PINC = 1
[user]$ ousb -h io PINC
 PINC = 0x1
[user]$ ousb -b io PINC
 PINC = 0b00000001
[user]$ ousb adc 6
 ADC6 = 119
[user]$ ousb adc 5
 ADC5 = 481
[user]$ ousb io PORTB 0
 PORTB = 0
[user]$ ousb pwm-freq 1 7000
 PWM #1 on pin 4 operating at 5859.375000 Hz
[user]$ ousb pwm 1 30
 PWM #1 on pin 4 operating at a duty cycle of 0.301961
```

chip only requires some 12mA for its internal uses this leaves a lot of drive for external devices.

The RS232 interface (IC2) at the bottom left of the circuit uses a standard MAX232 chip to interface to the RS232 lines and to provide the ±3V power supplies needed to drive the RS232 outputs. The device not only handles transmit and receive, but also one status line in and one status line out. If the RS232 port is not needed for serial data, then the two output lines can be used as general purpose outputs that drive around +3V and –3V.

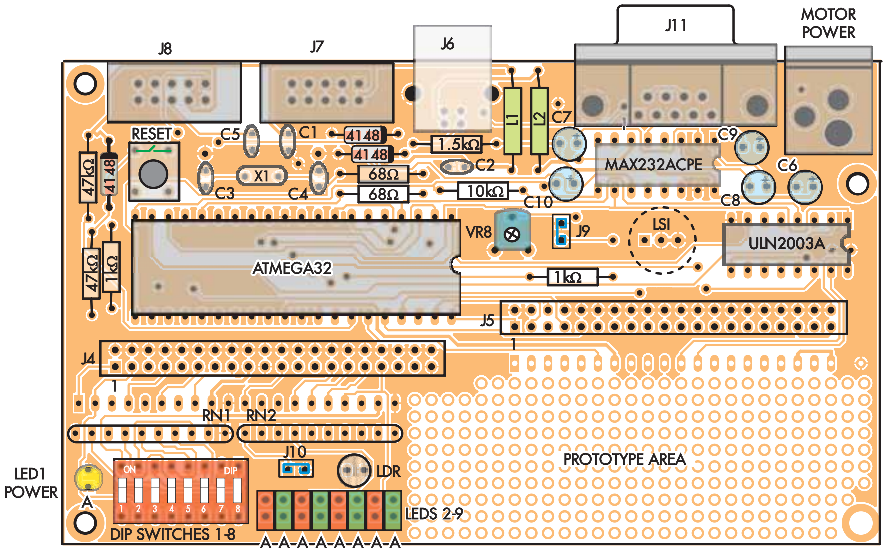


Fig.3: PC board layout, looking from the top (component side). The PC board is double-sided but the bottom tracks are not shown for clarity.

Darlington drivers

The right side of the circuit shows IC3, the open-collector drive chip ULN2003A, which has seven open-collector drivers.

Fig.2 shows the circuit of one of the Darlington drivers. An input of 3V or more applied to the 2.7kΩ resistor will turn on the Darlington transistor and current can flow from V_{SUPPLY} through the load to ground. If the input goes to 0V, the Darlington turns off and the load current drops to zero.

If the load is inductive, the built-in diode connected to the positive supply will short-circuit the inductive current and ensure there are no large voltage spikes that could destroy the chip.

The V_{SUPPLY} is not tied in any way to the board +5V, and can range from 0V to 50V. The Darlingtons can handle 500mA, so each of the seven drivers can control a small DC motor or a coil in a stepper motor.

Students at RMIT university have used such a configuration to drive one 6-wire stepper motor (using four outputs) and three DC motors or servo units. The power for these motors is usually connected to the 2.5mm DC socket (centre pin positive) which corresponds to V_{SUPPLY} above.

If you use the USB +5V as described above and your commands to Open-USB-I/O start to generate errors, then it is likely that the output devices are drawing too much current from the USB port.

Connectors

The two 20-pin IDC connectors, J4 and J5, provide access to most of the microprocessor pins and all the open-collector drivers. The back row of these pins are all connected to 0V. When a cable is connected, this means each signal wire has a 0V wire on each side. This helps to stop interference both to and from the signal wire. Without such an arrangement, a signal on one wire will usually create glitches on the wire next to it in the cable.

The pins on the 20-pin IDC arrays can be connected via easy-hooks or a proper cable, as can be found in older computers (often on the side of the road) that use IDE drives. The right connector also has seven open-collector drivers powered from the motor power plug (top right of board).

The RS232 port provides a serial data link that is entirely at the user's control; it's not used for any programming or control function.

The USB socket takes a standard USB A-B printer cable, which provides +5V power from the PC. Code on the microprocessor enables the board to act as a standard USB device and allows the ousb program on the PC to directly control every register in the microprocessor and hence every hardware interface.

The ISP socket (J7) conforms to the older STK-200 programming interface standard, which is supported by many programmers. Using this you can download your own code into the microprocessor or reload our USB interface code.

The JTAG interface (J8) allows an in circuit emulator (ICE) to be connected and provide powerful debugging facilities. Such ICE devices cost anywhere from about £35 to many hundreds of pounds.

If you are doing serious development work that needs debugging, then an ICE can save you a lot of time by making it much quicker to find errors. You won't need either of these sockets

BASH script file example

```
                        #!/bin/bash
                        #
                        #----- BASH script to read the LDR light sensor and
                          write the value to the LEDs.
set –u                  # stop autodeclaration of variables.
LDR=
until [ 0 != 0 ]        # A forever loop, control-C from the keyboard to stop.
do
sleep 0.3               # pause for 300 ms.
LDR=$(ousb adc 6)       # get the LDR reading from Open-USB-I/O
let "LDR = LDR/4"       # scale the 10 bit ADC back to 8 bits.
ousb io PORTB $LDR      # write the value to the LEDs
done
```

if you just want to control the I/O ports from your PC.

Lastly, the prototype area is big enough to add your own hardware, for example a motor, a relay or a number of opto-isolators.

Obtaining the software and hardware

There are several key resources that will help you understand much more about Open-USB-I/O and provide all the required hardware, programs and circuit diagrams.

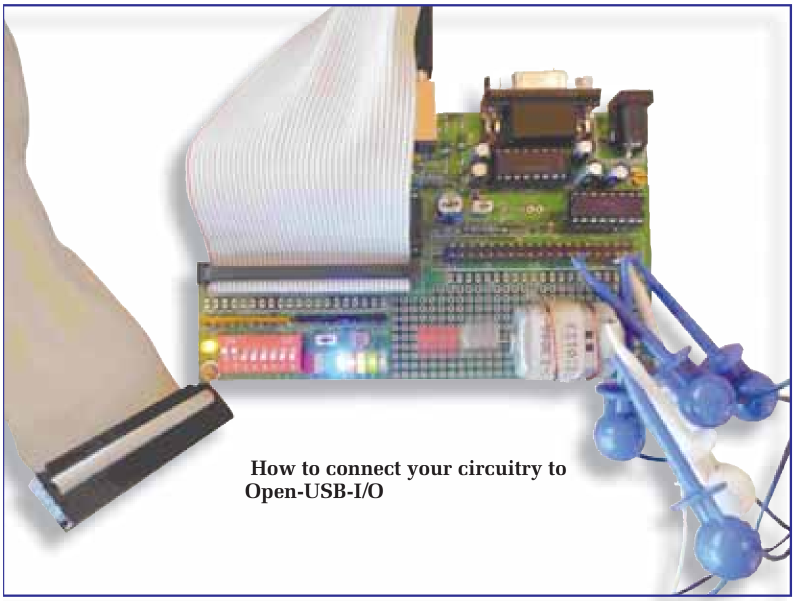
The website **http://pjradcliffe.wordpress.com/** has:

- A reference manual, which covers the USB commands in more detail, how to program the board from script files (**.bat** under Windows or **BASH** under Linux), how to write and download your own C programs onto the ATMEGA32 and a description of various development tool chains.
- The Windows and Linux programs that give the **ousb** command line functionality described later in this article. Normally, the firmware is pre-programmed into the Open-USB-I/O board, but the website has the firmware and instructions on how to program it into the board.
- Hardware circuit diagrams for the Open-USB-I/O board and a simple programming cable which enables you to download your own programs into the board.

The website **http://interestingbytes.wordpress.com/** supplies the Open-USB-I/O boards and also has a live-DVD with a huge range of development tools. This bootable DVD provides an excellent and surprisingly easy-to-use Linux system running straight off the DVD.

Live-DVDs do not touch the hard disk, they run from just your DVD drive and the RAM. However, if you like the live-DVD then it takes only 15 minutes to install it as a dual boot to the hard drive.

To boot the live-DVD, ensure your BIOS is set to boot first from DVD, then put in the DVD and restart the computer. When the desktop appears, double click on the **readme.html** file and read through the help and how-to information. Key features on the live-DVD relating to the Open-USB-I/O board include:



How to connect your circuitry to Open-USB-I/O

- Code editors and avr-gcc C compiler and assembler for Atmel microprocessors.
- The VMLAB emulator that enables you to simulate your code, including hardware, before downloading the code to real hardware.
- An excellent set of examples, which can serve as the basis of your own projects.
- A variety of useful documentation, including all data sheets for the ATMEGA32 and Open-USB-I/O board.

The live-DVD has an extensive array of other development tools for Linux, including the Eclipse IDE for C, C++, java, python, Perl, and C for the ATMEGA32. Other tools include Apache web server, MySQL database server, PHP, web editors such as Kompozer, Qt Designer for GUI development and much more. There is also a whole range of network tools, drawing tools, Open Office, audio-visual programs, and a few games.

Construction

The Open-USB-I/O is available in kit form or built and tested. The pre-assembled version is only slightly more expensive than the kit version and available from **http://interestingbytes.wordpress.com/**. However, any hobbyist with reasonable soldering skills should be able to build the board themselves.

The following is for those constructing from a kit. Using the component layout of the PC board (Fig.3), start with the IC sockets, ensuring that pin 1 of each is properly orientated. The notch at one end of the socket should match the notch in the socket outline on the board.

Next, solder in the sockets on the back edge of the board, the two shrouded IDC connectors, the USB connector, the RS-232 connector and the DC power connector. Note that the notch in the two shrouded IDC connectors should face the outside of the board.

As you solder in the two 20-way IDC connectors, be careful that they are sitting flush to the board and solder one pin on each end first. Do not apply heat for too long to any pin as the plastic can melt and the pin will shift, making it impossible to place a plug into the socket.

Now it is simply a matter of placing and soldering in the rest of the components, starting on one side of the board and moving to the other side. Be especially careful with all polarised devices such as electrolytic capacitors and LEDs.

Finally, insert the ICs into their respective sockets (again, watch the polarity) and do a careful visual inspection, checking the board against the photos and the overlay diagram of Fig.3. Don't forget to put in link J10 directly above the LEDs or the LEDs will not light!

Power up by connecting the board, via a USB cable, to a powered-up computer.

The yellow power LED should immediately light. If not, check for shorts between +5V and ground on the board.

Start playing

The simplest way to control the Open-USB-I/O board is via the command line.

On a Windows computer, copy the **ousb.exe** file from **http://pjradcliffe.wordpress.com/** to My Documents. Start a terminal by clicking the start icon, select Run, then type **cmd** in the command box and hit enter. Use the command cd 'My Documents' (change directory) to move to where you have saved the **ousb.exe** file.

For Linux, copy the **ousb** file to somewhere convenient. The location /usr/local/bin is a good place for programs, as this is in the path. Another good place is your home directory.

Check the program works by typing just **ousb** in the command window, help information should be displayed (if you are using your home directory on Linux use **./ousb**).

To begin, let's control the LEDs. First, ensure link J10 directly above the LEDs is plugged in. Type the command ousb io PORT B 85 and every alternate LED should be lit. This command is writing to PORTB of the microprocessor, which is connected to the LEDs.

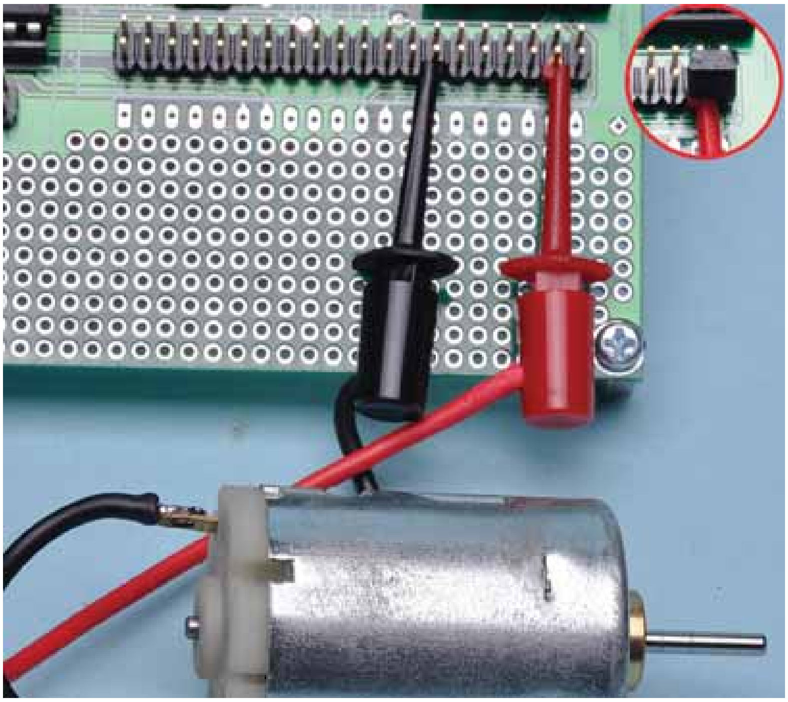
Now try ousb io PORTB 0xFF, which will light all LEDs and uses a hexadecimal number with all bits set high. To turn off the LEDs, use the number 0. Next try reading the switches, first set all switches to ON and try the command ousb io PINC. The result should be zero. Now try setting any switch and issue the command again. The result should show a one bit for each switch turned off.

To view it in hexadecimal try ousb –h io PINC, to see the result in binary try ousb –b io PINC.

The LDR is a slow responding light detector. Try the command ousb ADC 6 to see the light level. Try different light levels and turning the LEDs on and off, to see changes in the reading.

The trimpot provides a convenient analogue input, use the command ousb adc 5 to read the setting. Try adjusting the pot and note the reading changes.

If you have some easy-hooks and a small DC motor then you can use the PWM and the motor drivers. PWM generates a fixed frequency square wave, but varies the 'on' period (duty cycle).



Connections to drive a small motor with the pulse width modulator. Inset top right is the J5 37-39 jumper required to drive the motor from USB port +5V.

A motor responds to the effective average voltage, so if the duty cycle is 10% then the effective voltage to the motor is 0.5V, and the motor will probably not even move. However, for a duty cycle of 90% (which translates to an average voltage of 4.5V), your motor will spin freely.

There are two ways to get power for the motor. The first is to use an external power source that plugs into the 2.5mm DC socket (centre pin positive) on the board – in this case the motor can be connected between pin 27 and pin 37 of J5.

The second approach is to use the +5V supplied by the USB which should be OK for a *small* DC motor. If you are using this method you will need to link pin 39 and pin 37 of J5.

The photograph above shows both options. Note that the red and black connections are required for both, while the jumper between pin 39 and pin 37 of J5 (inset in red) is only required for option two, in order to use the USB +5V to drive the motor.

The first PWM output can only operate at four set frequencies and the output is connected to LED3 as well as an open-collector driver.

First set the LEDs to off using the command ousb io PORTB 0, and then set the frequency of the PWM to say 7kHz using the command ousb pwm-freq 1 7000. Note the frequency will be rounded to one of the several fixed values available.

Now set the duty cycle to 50% with the following command: ousb pwm 1 50. LED2 should now be at half intensity. Try other duty cycles to see the intensity change, or if you have a motor connected then the motor speed will vary as the duty cycle changes.

Advanced play

The ousb io command allows the user to access any register in the microprocessor and so gain full access to all the on-chip peripherals, which include extra timers, I^2C interfaces, more PWMs, interrupts, input time capture, the RS232 interface and more.

As an example let's take port B, which is an output by default and then make it an input.

First use the command ousb io PORTB 255 to turn on all the LEDs.

Next, the data direction register for port B must be altered – use ousb io

DDRB to read the current value, then ousb io DDRB 0 to turn all the pins to inputs which should turn off all the LEDs. Add the command ousb io PORTB 0 to turn off the microprocessor's 100kΩ pull-up resistors, which may cause the LEDs to glow dimly.

Now try the command ousb io PINB to read the inputs. Use an 'easy-hook' or similar to connect the J4 pin for port B bit 0 (pin 21) to +5V (pin 37) or 0V (any even pin). Read the value of the pin using ousb io PINB. To restore the microprocessor to its default state first remove all connections and then hit the reset button.

Any **ousb** command can be placed in a script file; a **.bat** file for Windows or a BASH script file under Linux or Macs.

The Windows **.bat** files are not very powerful compared to Linux BASH script files. Under Windows you can download a package called cygwin (**www.cygwin.com**). This gives you a Linux command line and BASH script capability on Windows.

With a BASH script you can now write complex programs to control your Open-USB-I/O board. For example, the BASH script file earlier reads the light dependent resistor (LDR) and writes the reading to the LEDs.

Starter projects to power projects

The ATMEGA32 is a cheap yet very powerful microprocessor and quite amazing things can be done with it. The web is filled with the hardware and software that you can download for free.

For example, Neil Franklin on his website **http://neil.franklin.ch/Projects/SoftVGA/** shows how to drive a VGA display from the ATMEGA 32 with just six resistors. Austin Lu and Albert Ren show to build an iPod interface (**http://dev.emcelettronica.com/how-to-control-ipod-atmel-mega32**).

Perhaps you are just beginning, how about just flashing an LED (at **www.dharmanitech.com/2008/10/adc-project-with-atmega32.html**).

Some of the best projects and information can be found at **www.avrfreaks.net**; here you can find tools, data sheets, getting started information and projects ranging from the simple to the extreme.

Low speed activities (below 1kHz) can be driven from the PC via command line, script, or C/C++ code. Higher speed activities need to be programmed directly on the ATMEGA32 microprocessor.

Conclusion

The Open-USB-I/O board is an easy and inexpensive way to achieve digital and analogue I/O from your laptop or desktop using just the USB port. It will work on Windows XP, Vista, Mac OSX, Linux and other POSIX operating systems without the need for special drivers.

The board contains a whole range of I/O pins, pulse width modulators, analogue inputs, motor drive pins, and more. The board also contains the powerful ATMEGA32 microprocessor and using the live-DVD you can write your own assembler or C code, then download it into the ATMEGA32. The live-DVD has several project examples which can serve as the basis of your own projects.

We have found the Open-USB-I/O board very useful at the School of Electrical and Computer Engineering at RMIT University (Melbourne, Australia). It can be used in simple first-year programming activities right up to final-year microprocessor subjects that require students to use the full complexity of the ATMEGA32.

The board is used in our major project activities which are both fun and very important to our students (employers want evidence that students can achieve things not just be good at passing exams!). Hopefully, you will find Open-USB-I/O as useful as we have.

We are developing more useful tools based around Open-USB-I/O including a GUI controller and the ability to program the ATMEGA32 just through the USB connection.

Check the websites below in the near future to get these tools.

Where do you get it?

See **www.interestingbytes.wordpress.com** to purchase an Open-USB-IO board and the live-DVD which contains development tools and example projects.

See **www.pjradcliffe.wordpress.com** for a detailed reference manual, and all the programs that you will need.

INTERFACE

By Robert Penfold

USB-to-serial interface

A PREVIOUS *Interface* described a circuit based on an FT245RL chip that provided an output port without the need for a microcontroller to handle the flow of data from the PC. Instead, some simple control logic was used to provide a latching output port. The control logic also provided a pulse each time a fresh byte of data became available, which, in practice, would be used to indicate to the main circuit that new data had to be processed.

The FT245RL connects to a USB port, but provides what is essentially a virtual RS232C serial interface, which is, of course, a two-way type. Therefore, in simple applications it should also be possible to have an 8-bit input port based on the FT245RL that does not utilise a microcontroller, but instead relies on some basic control logic.

In some applications it would be necessary to integrate the FT245RL interface with the control logic of the main circuit. In more basic applications, the interface could be designed to periodically read the data bus and transmit the data.

Flat out

One slight drawback of the FT245R range of chips for electronics experimenters is that it is only available in various flat-pack packages for surface mounting, and these have the pins/pads spaced at a fraction of a millimetre. This makes them difficult to use, and probably rules them out as viable propositions for many potential users.

Fortunately, the FT245RL flat-pack version is also available in a development module called the UM245R. This has the pins at a more manageable 0.1-inch (2.54mm) spacing (Fig.1). It has a standard USB socket, so that the connection to the PC can be made using an ordinary lead of the type used with printers and scanners. As one would probably expect, this is a relatively expensive way of using the FT245RL chip, but for most people the ease of use it provides will more than justify the extra cost.

There are two small terminal blocks with 'jumpers' so that the required configuration can be set (Fig.2). A jumper should be placed across pin 2 and pin 3 of the J1 block so that the input and output lines operate at normal 5V CMOS logic levels. These lines operate at 3.3V logic levels if pins 1 and 2 are connected. Pin 1 and pin 2 of the J2 block are connected together if the module is to be powered from the USB port, but this link *must* be removed if it will be powered from a different source.

The default settings should be for 5V logic levels and for power to be taken from the USB port, which are the ones that will normally be required in the current context. However, as always with this type of thing, it is best to check that everything is present and in the right place.

The basic circuit for the FT245RL chip, when it is powered from the USB bus, is shown in Fig.3. As the circuit only consumes about 15mA from the power lines of the USB port, there is no point in using a separate supply unless the main circuit exceeds the 500mA available from a USB 1.1 port, or the 2A that can be supplied by a USB 2.0 type. The circuit has a built-in 12MHz clock oscillator, and although there is provision for using an external type, there is normally no reason for doing so.

Software driven

Of course, in order to communicate with an interface based on the FT245RL it is necessary for the PC to have suitable driver software installed. A suitable driver is available as a free download from the chip manufacturer's website (**www.ftdichip.com**), but it will often install automatically if you are using a modern version of Windows.

An FT245RL-based interface will appear in the list of COM ports in

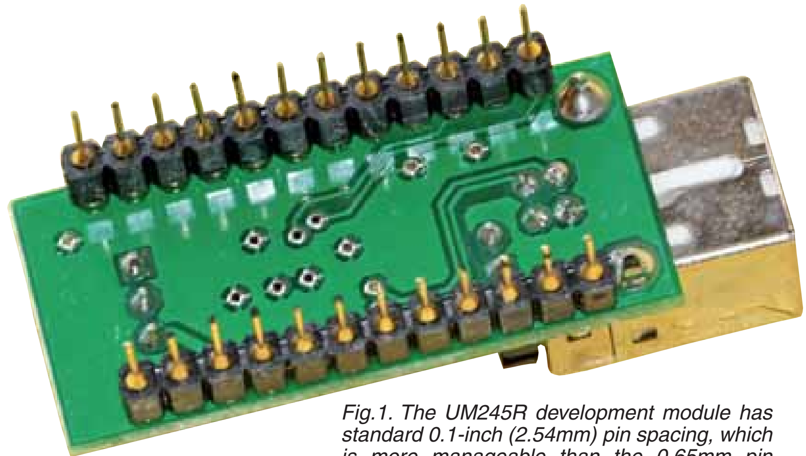


Fig.1. The UM245R development module has standard 0.1-inch (2.54mm) pin spacing, which is more manageable than the 0.65mm pin spacing of the FT245RL chip it contains.

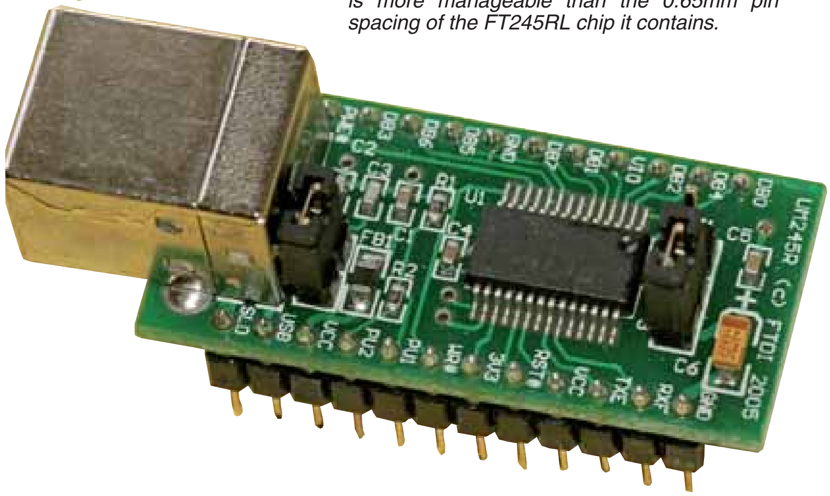


Fig.2. There are two jumper blocks that are used to configure the UM245R. The default settings provide input/output lines that operate at 5V CMOS logic levels, and connect the unit to the supply output of the USB port

Windows Device Manager once the correct driver software has been installed. It can then be accessed via software in the same way as a genuine (non-virtual) COM port, provided the software goes via the proper Windows approved route.

Direct access via input/output addresses is not possible with this type of interface, even when using an old version of Windows that supports this method, since the virtual port does not actually occupy any input/output addresses.

The required baud rate and word format can be set via Device Manager in the normal way, and any 8-bit word type will suffice. The baud rate needs to be fairly high, such as 9600 or 19200 baud, since the maximum rate at which data can be transferred to the PC is governed by this factor, and not the usual USB limits.

Bidirectional bus

The FT245RL is effectively a USB-to-RS232C converter, with a built-in UART (universal asynchronous receiver/transmitter). However, a conventional UART has separate input and output busses, whereas the FT245RL has a bidirectional 8-bit data bus (D0 to D7 in Fig.3).

This is an important difference, because a normal UART can send and receive data simultaneously via what are effectively separate items of hardware. The FT245RL can simultaneously send and receive data internally, but externally the data bus must be devoted to one function or the other.

This normally means using a microcontroller to deal with the FT245RL's control bus and provide the required input and output ports. In a simple application it is by no means essential to use a microcontroller though, and some control logic is all that is needed. The control logic can be very simple indeed in applications where it is only necessary to send or receive data and a two-way link is not required.

In fact, things could be kept very simple, even if two-way communication is required. As modern PCs are not exactly short of USB ports, having separate FT245RL interfaces for sending and receiving data would be a perfectly viable way of providing a PC with 8-bit input and output ports. It would not necessarily cost much more than using a single FT245RL plus a microcontroller or other sophisticated control logic circuit.

Anyway, there is one main problem to avoid if the interface is only required for sending data, and this is to ensure that the FT245RL never tries to place received data onto the data bus while the circuit feeding it with data for transmission has active outputs. Of course, this state of affairs should never arise, because data should not be sent to the port.

If no data is received, it will never be placed on the bidirectional data bus. In practice, there is always a slight risk of things not going quite according to plan,

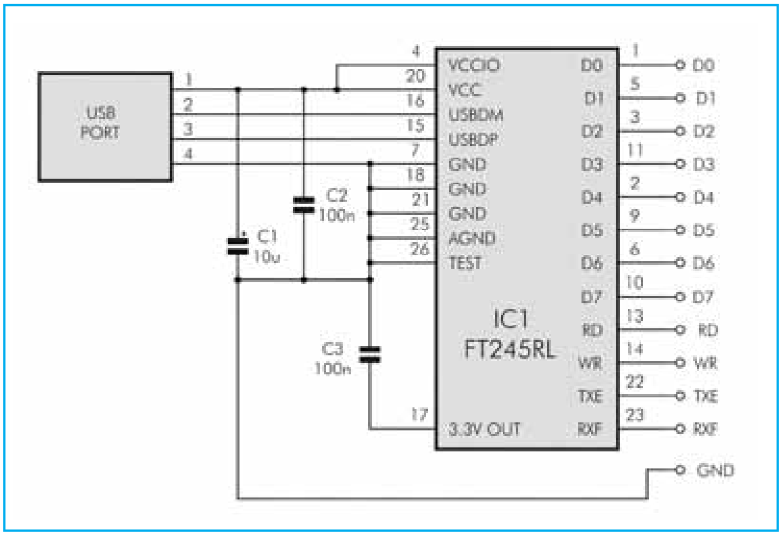


Fig.3. The basic circuit for using the FT245RL with 5V input/output levels and power obtained from the USB port. An external clock can be used, but using the internal 12MHz clock, as here, is normally sufficient

and ideally the hardware should be designed to deal with an error condition.

The RD and RXF pins are the control lines used when reading data, and they are an input and an output respectively. RXF is normally high (logic 1), but it goes low (logic 0) when a complete byte of new data is available to be read. The new data is not placed on the data bus automatically, and in order to read a new byte it is necessary to take the RD input low. The data bus is then read, after which the RD input is taken high again. The RXF output is automatically returned to the high state once the strobe pulse on RD has ended.

The fact that the FT245RL will not automatically place data on the bidirectional data bus makes it easy to avoid conflicts on the bus when using the chip solely to send data. There is no need to feed data to the chip via a tri-state buffer or anything of this ilk. Instead, it is merely necessary to hold the RD input in the high state, which ensures that any data sent to the chip in error will never be placed on the bidirectional bus. The RXF output can simply be ignored, or it could be used to drive an indicator light that would show that an error has occurred if it should go to the active (low) state.

Flow control

Getting the FT245RL to transmit data is fairly straightforward. The TXE output is used to indicate whether it is all right to transmit a new byte of data, and it goes high to indicate that a hold-off is required. Even when using a high baud rate, the speed at which the interface can transfer data is not very great, and in some applications there could be a risk of data being fed to the interface at an excessive rate.

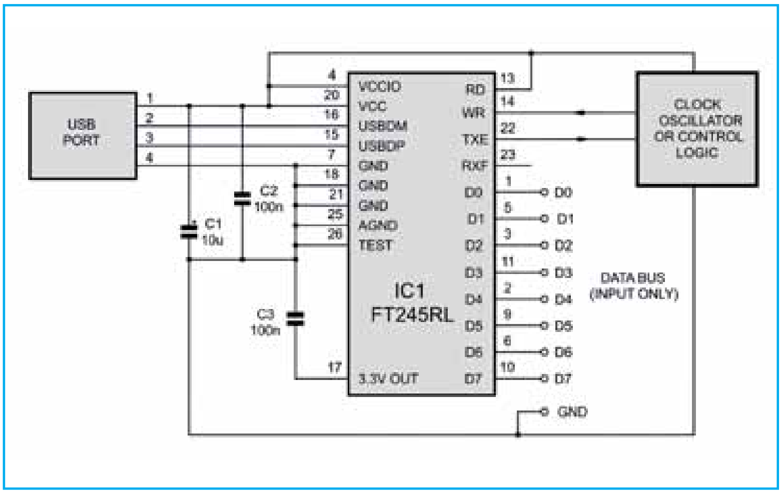


Fig.4. The basic arrangement used when the FT245RL is used only as an input port. Use of the TXE output is optional, but data must not be sent to the interface at an excessive rate if it is left unused

One way of controlling the flow of data into the interface is for the control logic to monitor the TXE output, and only transmit new data when it is low.

This method is only needed in applications where data is being sent at a rate that could cause problems. With something like a temperature monitor it might only be necessary to send a byte of data a few times per second, or perhaps even just a few times per minute or hour. Overloading the interface with data will not be a problem in applications of this type, and the TXE output can then be left unused.

The basic circuit for the FT245 when sending data is shown in Fig.4. The RD input is tied to the +5V rail in order to prevent any received data from being placed on the data bus, and the RXF output is just ignored. In order to send the byte of data currently on the bidirectional data bus, which here effectively becomes just an input bus, it is merely necessary to provide a pulse to the WR (Write) input of the FT245RL.

It is on the falling (high-to-low) transition of this pulse that the data is latched into the FT245RL, and transmission of the data then commences. The pulse width must be at least 50ns.

Where the interface is being fed from something like an analogue-to-digital converter, there may well be a suitable pulse already available from the converter's control logic. There should at least be a pulse that can be used after a certain amount of processing, such as an inversion or a short delay.

There will not be any control logic in a very basic application, such as when reading switches or simple sensors. It is then just a matter of using an oscillator circuit to briefly pulse the WR input low so that the data bus is read at the required rate.

The main point to bear in mind here is that the rate at which data is fed to the interface must be kept below the maximum rate that can be handled by the particular baud rate in use. There are ten bits in total when using a word format of one start bit, eight data bits, and one stop bit with no parity, giving a maximum byte rate that is one tenth of the baud rate.

In practice, it is unlikely that the full theoretical maximum could be achieved, and it is therefore advisable to have the oscillator running at no more than about one twelfth of the baud rate. With the baud rate at 9600 for example, an oscillator frequency of about 800Hz represents a safe upper limit.

In many applications, it is merely necessary to have readings taken at a high enough rate for on-screen readings to be quickly updated when data changes. A frequency of around 50Hz is more than adequate for this type of thing. In data logging applications, where only very occasional readings are taken, it is likely that the frequency of the oscillator would be impractically low. The normal solution in this situation is to have a relatively high clock frequency with a divider chain to give the required one cycle per minute, hour, or whatever.

It should be borne in mind that it is not good practice to have the hardware running while the matching software in the computer is not operational. The data from the interface will still be read by the computer and stored in a buffer, which before too long will probably become full.

This is unlikely to have major consequences, but it will leave old data in the buffer which will be read when the software is run. Ideally, the software should be designed to 'flush' the buffer before starting to operate in earnest.

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Input and output impedance

CHAT ZONE user ***afferrari*** posted the following question about input and output impedance.

I am trying to grasp properly the concepts of output impedance and input impedance. Regarding the first, I think I have a minimal idea, but trying to calculate it in a real case, I fail miserably. For the attached circuit (Fig.1) I need to know the source impedance.

My questions:

a) Given the filter, what is the source impedance? Can you tell briefly how do you calculate (or just estimate) it?.

b) If I apply V_{out} (as V_{sig}) to the resistive divider, what is the source impedance at the output where I get V_{div}? Can you tell again, how do you calculate (or just estimate) it?

Input and output impedance

This month, we will look at the concept of input and output impedance and answer afferrari's second question (on the divider), continuing next month with a look at the filter circuit in more depth.

Fig.2 shows a generalised situation in a circuit where a source or output is connected to a load. This is an abstract representation of a vast range of possible cases where two electronic circuits or devices are connected together.

The source may be the output of a circuit, such as an amplifier or filter or, it may be a sensor such as a microphone or photodiode. It could also be a power source such as a battery. The load may be the input of a circuit such as an amplifier or filter, or it may be a transducer such as a loudspeaker or motor.

This general representation of interconnected circuits is, of course, a simplification which has restrictions on its applicability.

A source may produce either voltage or current (see Fig.2a and Fig.2b respectively) internally. If the source is ideal then the voltage or current produced internally (V_S and I_S respectively in Fig.2) will be exactly the same as that seen externally (V_x and I_x respectively in Fig.2). The power output available from an ideal source is infinite and obviously this is not something we find in the real world.

All real sources have output impedance or internal resistance (Z_{out} in Fig.2). The term 'output impedance' is usually used for signal sources and 'internal resistance' is used for power sources. However, the representation is as shown Fig.2 in both cases.

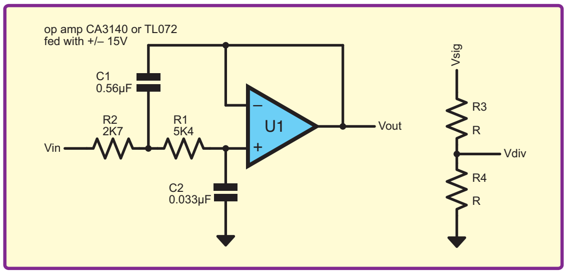


Fig.1. Copy of afferrari's circuit diagram

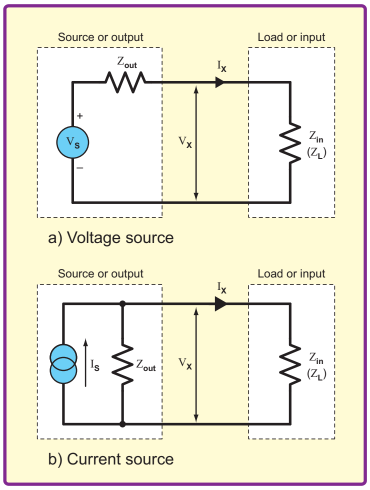


Fig.2. Generalised representation of two electronic circuits or devices connected together – a source or output is connected to a load or input. The source may be represented as producing either a) a voltage, or b) a current internally

Use of the term impedance rather than resistance implies that the value varies, or may vary, with frequency, or that the circuit is being analysed in terms of frequency response. Put another way; output impedance may be a mixture of resistive, capacitive and inductive qualities, whereas output (or internal) resistance is simply a resistance.

Voltage source

For a real voltage source (Fig.2a) with output impedance Z_{out}, some of the internal source voltage is dropped across Z_{out} due to the current, I_x, flowing through it. Thus the output voltage, V_x, is less than the internal source voltage. The smaller the load impedance (or resistance) connected across the source (Z_{in} or Z_L in Fig.2a) the larger the current the voltage source has to deliver to attempt to provide V_S across the load.

As Z_L decreases V_x decreases and a greater proportion of V_s is dropped across Z_{out}. The output impedance limits the minimum load impedance to which a reasonable proportion of V_s can be delivered and also limits the maximum possible power output.

Current source

For a real current source (Fig.2b) with output impedance Z_{out}, some of the internal source current is diverted via Z_{out}. Thus, the output current, I_x, is less than the internal source current, I_s. The higher the load impedance (or resistance) connected across the source (Z_{in} or Z_{Lin} Fig.2b) the larger the voltage the current source has to produce to attempt to provide I_S through the load. As Z_L increases V_x increases and a greater proportion of I_s flows through Z_{out}. The output impedance limits the maximum load impedance to which a reasonable proportion of I_S can be delivered and also limits the maximum possible power output.

It follows from the previous paragraphs that if our signal is a voltage and we wish to preserve its amplitude it is best to have Z_{out} as small as possible, and Z_L as large as possible. Similarly, if our signal is

a current and we wish to preserve its amplitude it is best to have Z_{out} as large as possible, and Z_L as small as possible. We see that current and voltage sources have opposite or dual properties.

Voltage signals

The circuit posted by atferrari uses voltage signals, so we will look at this in more detail. In Fig.2a the two impedances form a potential divider. Thus the voltage across the load is given by:

$$V_x = \frac{Z_L}{(Z_{out} + Z_L)} V_s$$

We get this equation by using Ohm's law to get the current through the two impedances (V_s divided by the total impedance) and applying Ohm's law again to get the voltage drop across Z_L (by multiplying Z_L by the current). From the equation we confirm that if we want V_x to be as large as possible then Z_L must be much larger than Z_{out}. If Z_L is very much larger than Z_{out} then the load voltage is effectively equal to the source voltage.

The current in the load in Fig.2a is given by:

$$I_x = \frac{V_S}{(Z_{out} + Z_L)}$$

Thus, if we want the current in the load to be as high as possible we need to make Z_L much smaller than Z_{out}.

When connecting a source to an input such as an amplifier the loss of (voltage) signal in decibels due to loading by the input impedance (load loss) can be calculated as follows:

$$Load\ loss = 20\log\left[\frac{Z_L}{(Z_{out} + Z_L)}\right]$$

In general, it is a good idea to have Z_L at least ten times as large as Z_{out} if you want to avoid loading. This results in a load loss of less than 1dB.

Matching

Discussion of input and output impedance often raises the issue of matching. Given that the term 'matching' would imply $Z_{out} = Z_L$, the two scenarios we have just looked at – maximum V_x by making Z_L much larger than Z_{out}, and maximum I_L by making Z_L much smaller than Z_{out} indicate what happens when load and source are not matched.

So what happens when the circuits are matched with $Z_{out} = Z_L$, and why might this be useful? The answer is that maximum power is transferred from source to load. In order to prove this you have to use calculus to find the maximum of the relationship between load power and load resistance.

In general, we should be asking what is the most appropriate load for this source. Matching in the sense of $Z_{out} = Z_L$ is not always what we want. For example, a high impedance input (Z_L much greater than Z_{out}) may be most appropriate for amplifying the voltage from a sensor. In fact, in very many cases circuits are designed to have much larger input impedance than the source impedance so that loading does not modify the voltage at the input. On the other hand, if our signal is a current we usually want to have low input impedance.

In theorem

We started this article with the rather sweeping statement that a large range of circuits and interconnection scenarios could be represented by Fig.2. Where does this come from? The idea of representing the output of a complex circuit, such as amplifier or filter, by a single voltage source and resistor is based on Thévenin's theorem. The theorem is named after Léon Charles Thévenin (1857–1926), a French telegraph engineer; although the theory was also developed 30 years earlier, in 1853, by Hermann von Helmholtz (1821–1894).

Thévenin's theorem states that a linear electronic circuit that comprises any combination of voltage sources, current sources and resistors, with two output terminals, is electrically equivalent to a single voltage source, V_s, and a single series resistor, R_{out} (Z_{out} in Fig.2a). The theorem also applies to circuits in which the sources are AC (sinewave), all at the same frequency, and the other components are impedances (resistance, capacitance inductance).

There is a related theorem, called Norton's theorem, which states that a linear electronic circuit that comprises any combination of voltage sources, current sources and resistors with two output terminals is electrically equivalent to a single current source, I_s, and a single parallel resistor, R_{out} (Z_{out} in Fig.2a). This can also be extended to single frequency AC sources and impedances.

We can also readily convert from a Thévenin to Norton equivalent or vice versa if required. The theorem dates from 1926, and is named after Edward Lawry Norton (1898–1983), who was an American engineer.

To find the Thévenin equivalent circuit for any suitable circuit we first find the open circuit output voltage (our circuit's output voltage with no load connected). This is the Thévenin equivalent voltage (V_S in Fig.2a). Next, we find the short circuit output current, I_{sh}, that is the current which would flow in zero resistance wire if we connected it across our circuit's output terminals. The Thévenin equivalent impedance (Z_{out} in Fig.2a) is then given by V_S/I_{sh}. The Norton calculation follows a similar pattern.

Thus, any circuit or device, where we are concerned with a single output signal, and which meets the above criteria, can be represented by a Thévenin or Norton equivalent circuit. Here we meet a possible objection – most of the circuits we are interested in are built using devices such as transistors and op amps, which are not linear over all operating conditions (eg, transistors switch off, op amps saturate); but the theorem requires a linear circuit.

The concept of equivalent circuits is very important in circuit analysis. Thévenin and Norton's theorems provide perfect equivalents in terms of voltage and current (but not internal power dissipation), under the stated conditions. However, we do not always need a perfect equivalence; if we limit the conditions of our analysis we can then apply the theory more widely and still get very useful results.

Small signal analysis

Input and output impedances are typically calculated and used in the context of what is called *small signal analysis* (even if you do not realise it). As the name indicates, we implicitly assume a very small signal amplitude, which means that transistors are staying very close to their bias conditions. We can ignore the DC bias conditions in our analysis because they do not change, and we can use linear models of transistors etc. because the implied small signal amplitudes mean that they will not do grossly non-linear things like switching off.

Small signal analysis is used to calculate things such as the gain and frequency response of a circuit, and is the basis of AC analysis (frequency response analysis) in SPICE analogue circuit simulators such as LTSpice.

The well known idea of a bipolar transistor having a *fixed* current gain (β or h_{fe}) is an example of small signal linearisation. We can multiply the base current by the gain to get collector current as long as the transistor is biased correctly – the current gain does not apply if the transistor is off, so this view of the transistor is a simplification which does not encompass its full range of behaviour. Actually, the gain varies with bias, but if we use fixed bias and assume a very small signal we can also assume a fixed gain and hence a linear transistor.

Using our simplified, linear, small signal view of the transistor we can replace all the transistors in our circuit with current sources (eg, to produce the collector current) plus other basic components such as a resistor to represent base-emitter

Table 1: Fig.3 symbols

V_s	Signal source Thévenin equivalent voltage
Z_s	Signal source output impedance
V_{in}	Filter input voltage = Source output voltage
I_{in}	Filter input current = Source output voltage
Z_{inf}	Filter input impedance
V_f	Filter output Thévenin equivalent voltage
Z_{outf}	Filter output impedance
V_{sig}	Filter output voltage = Divider input voltage
I_{sig}	Filter output current = Divider input current
R_{div}	Divider input resistance (impedance)
V_d	Divider (plus filter) output Thévenin equivalent voltage
Z_{outd}	Divider (plus filter) output impedance
V_{div}	Divider (plus filter) output voltage

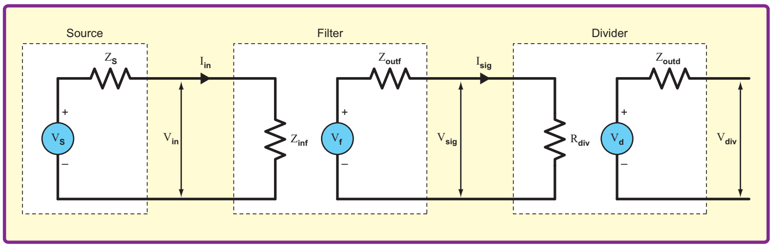


Fig.3. Equivalent circuit for Fig.1. Note that the source is not shown in Fig.1. Also note that $V_{sig}=V_{out}$ on Fig.1 when the filter is connected to the divider

resistance. The resulting circuit will contain just sources and passive components (the original resistors etc, plus those from our transistor equivalent circuits) and therefore can be worked on using the Thévenin or Norton theorems. Similarly, we can produce a small signal equivalent circuit for an op amp and analyse op amp circuits in the same way.

Fig.3 shows an equivalent circuit for afferrari's filter and voltage divider. We have also added a source, which produces V_{in}, but which is not shown in Fig.1. We can answer afferrari's questions with respect to this equivalent circuit and the original schematic. Table.1 provides a description of all the symbols in Fig.3.

Strickly speaking

If afferrari's first question about the source impedance with respect to the filter refers to the source in Fig.3, the question cannot be answered because no details of the source were provided in the question. If afferrari means the output impedance of the filter, then this is something we can address. However, the fact that the filter uses an op amp with feedback makes the situation more complex, so we will look at the second question first, assuming we already know Z_{ouf}.

Strictly speaking the divider does not have a full Thévenin equivalent circuit because it does not contain any voltage sources. However, we can find an equivalent circuit of the filter output combined with the divider. To do this we can take the filter's equivalent output circuit (V_f and Z_{outf} in Fig.3) and combine this with the original divider circuit. This is shown in Fig.4. If we find the Thévenin equivalent circuit for Fig.4, this will give us the Thévenin circuit for the filter and divider combined, and hence the output (source) impedance (Z_{outd}) which afferrari is looking for.

The short circuit output voltage for Fig.4 can be found by applying the potential divider formula in which (Z_{out} + R_A) form the upper resistor of the potential divider and R_B is the lower resistor. So we have:

$$V_d = \frac{R_B}{\left(Z_{outf} + R_A + R_B\right)} V_f$$

If we short the output of Fig.4, I_{sig} flows from V_f through Z_{outf} and R_A and then via the short to ground. The short circuit output current is therefore:

$$I_{sh} = \frac{V_f}{\left(Z_{outf} + Z_A\right)}$$

Dividing V_d by I_{sh} we get Z_{outd}

$$Z_{outd} = \frac{R_B\left(Z_{outf} + R_A\right)}{\left(Z_{outf} + R_A + R_B\right)}$$

Readers may notice that this is the resistance of Z_{outf} plus R_A in parallel with R_B. If Z_{outf} is very small compared with R_A (which may be the case, at least at low frequencies) then it may be ignored and Z_{outd} will be equal to the parallel resistance of R_A and R_B.

An alternative way to calculate the Thévenin impedance is to replace all voltage sources with short circuits and all current sources with open circuits and then calculate the impedance (resistance) between the output terminals. For Fig.4 it is straightforward to see that this gives us the same result as above.

This month we have introduced the theory behind the idea of output or source impedance and answered one of afferrari's questions. Next month, we will look at output impedance in the context of op amp circuits and have a look at the filter circuit in more

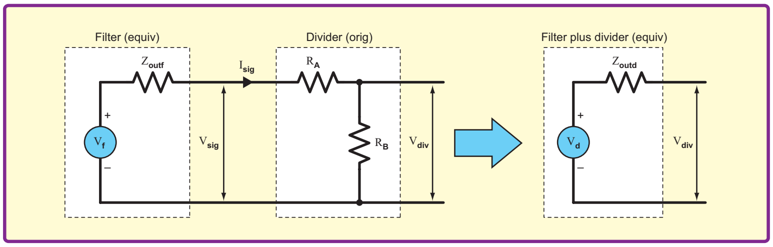


Fig.4. Filter output equivalent circuit connected to actual divider circuit. We can use this to find an equivalent circuit for the filter and divider combination

Max's Cool Beans

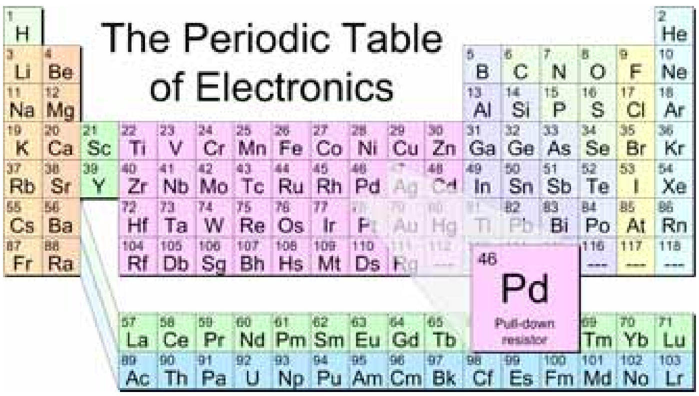
By Max The Magnificent

A periodic table of electronics

Don't ask me why, but I was recently looking at something called *The Periodic Table of Contra* [Dancing]. Apparently Contra is akin to what I used to know as barn dancing when I was a lad, where a caller shouts out the moves for the dancers to perform. Anyway, it seems that the creator of this table – April Blum – had seen other novelty periodic tables, and wondered if she could create one based on the terms the callers use during Contra dancing. The result is really clever. You can see a full-size version of April's table at: **www.cdss.org/tl_files/cdss/images/blog/PeriodicTableOfContra32.gif**

One thing I find really impressive about this is that there's no cheating; April used the real chemical symbols and worked really hard to make everything come out. From there I started bouncing around the Internet to discover that there are all sorts of funny tables, including *The Periodic Table of Fruits and Nuts*, *The Periodic Table of Deserts*, and *The Periodic Table of Fish Lures and Flies*, to name but a few.

Just a minute – I have an idea – and I bet you're thinking the same thing as me: 'Could we create our own *Periodic Table of Electronics*?' The idea would be to come up with electronic terms corresponding to all the regular element mnemonics. For example, element 46, symbol Pd, could equate to 'pull-down resistor' (this is just an 'off-the-top-of-my-head' throwaway thought – I'm open to any and all suggestions). I'm thinking that the full-up table will be about 17in across and 11in deep. If we do this, I'll make it available as a PDF that anyone can download and print.



So, how about it? Can we come up with an electronics item for each of the chemical symbols for elements 1 through 111? If you email your suggestions to me (**max@CliveMaxfield.com**) I'll create the table. Note that it's a lot easier from my point of view if you give me three things: the element number, the mnemonic, and your suggestion. Don't just email me saying something like 'How about, 'ho = Hold Time?' Finding things without the element number is a real pain; you try finding 'Ho' in the table above – you'll find that it's not as easy as you might think.*

You're never alone with a ukulele

A friend of mine recently told me that 'It's hard to be in a bad mood while you're playing or listening to a ukulele.' The reason for his confidence is that he's never heard me play (grin). In fact, I have never held one of these little scamps in my hands, but that is soon to change…

Have you ever heard a rendition of the song 'Somewhere Over the Rainbow' from the film *The Wizard of Oz* by a Hawaiian musician called Israel 'IZ' Ka ano i Kamakawiwoole (1959 – 1997). If you aren't familiar with this you really should check it out on YouTube (**www.youtube.com/watch?v=V1bFr2SWP1I**). I have to tell you, this really counts as one of the most beautiful things I've ever heard. Somehow IZ's voice and his ukulele meld together in perfect harmony (no pun intended). Whatever I'm doing, this always makes me pause for a moment's reflection and brightens my day.

Anyway, a few days ago I ran across a really inexpensive ($40) do-it-yourself ukulele kit (**www.uncommongoods.com/product/make-your-own-ukulele-kit**). In fact, this isn't as hard as it sounds because the main body is already constructed. All you have to do is add the supplied neck and strings and stuff. I couldn't help myself; I ordered two – one for myself and one for my 16-year old son. I just checked the online tracking and they are due to be delivered tomorrow as I pen these words.

The really cool thing is that you can paint a design on it if you wish. Originally, I was planning on a Hawaiian theme, but then someone who knows my interests said 'Why don't you give it a Steampunk look-and-feel?' (This is where you make something look like it's sort of Victorian with lots of brass and bolts and cogs and suchlike.) I hadn't even thought of this, but my imagination immediately ran away with me. I've thrown a couple of pencil sketches together and I think I can make this look really amazing.

Last but not least, I was pondering how I was going to tune the little rascal once I've painted and assembled it. Well, I recently took the plunge and purchased an iPad 2. So I performed a quick search in the iPad app store and found a plethora of apps geared up to tuning ukuleles (I know, I didn't believe it either). I just downloaded a free app called UkuTune that seems to work really well.

So now I'm aquiver in anticipation. I cannot wait for my DIY ukulele to arrive. Once I have it all painted and ready to rock-and-roll (as it were) I shall report further in a future column. Until next time – have a good one!

---

*One reason it's not easy to find the box corresponding to Ho (element 67) is that it's located underneath my zoomed-in Pd box, but I think you follow my drift.

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All letters quoted here have previously been replied to directly

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☆ LETTER OF THE MONTH ☆

Thinking outside the box

Dear Editor
I run a small company, and was recently speaking to a young friend who is in the process of setting up his own electronics business. In the course of our conversation, I warned him to consider enclosures as a major hurdle to any new product. Let's face it, many of us can design a PCB on a computer and email the design off to a manufacturer. For relatively little cost we can have a working gadget back in a matter of just a week or two. No, the big problem, as I explained, is the plastic box!

As I see it, there are two major hurdles to overcome. The first is that 'standard enclosure' manufacturers seem to have perilously little imagination and the vast majority of their products are all about the same shape – they just vary in size. Little thought is given to how a designer might actually use the box in practice, and if anyone is courageous enough to actually use one of these monstrosities then it generally looks very home made.

The second hurdle is that the main alternative to standard enclosures, ie, injection mouldings, is a hideously expensive process and is a major inhibitor to small, innovative companies. I know – I've just spent £6000 on a small moulding tool that will take a large number of sales to pay off. I have tried to persuade my suppliers to work on an innovative set of enclosures that could be built with PCB designers in mind, but I didn't generate much interest.

With all this in mind, I'm afraid my attention must now turn to my good friends at *EPE*, who as we all know publish excellent projects in every issue. My gripe with this is that the enclosure side of things is often left to the 'imagination' of the constructor.

Speaking personally, I'd appreciate it if all kits were designed to fit in some easily available box, ideally ones we can buy in the UK from suppliers like Maplin, RS or Farnell. I do understand that these articles are often reprinted from publications based in other countries, and if necessary, I for one would be happy to go further (eg, Jaycar) to buy the right enclosure if it had been specified in the instructions.

To summarise, PCBs are easy to make but enclosures aren't, so please ask your project designers to take this into account in their work.

Nigel Fraser Ker, Ashtead, Surrey

I completely agree with you Nigel, but as you have already discovered, it's not an easy problem to solve. An additional issue is that a half-decent enclosure can cost as much or even more than the silicon in a project. The projects that we share with Silicon Chip do need to use the enclosures specified, thereby ensuring that the designers' overall layout, in terms of EMC, power supply, thermal safety and other considerations is followed. However, if you or any other reader manages to find a good source of enclosures for other projects, then we would be delighted to hear from you.

On-the-cheap

Dear Editor
Re: 'Rat it before you chuck it', one might consider buying something new, specifically to cannibalise it for its constituent parts.

At one well-know supermarket recently, I was able to buy 48 white LEDs for £5 (built into a battery light), or 72 LEDs for less than £7, complete with three magnets, a battery holder, a pushbutton switch, and some power control electronics thrown in for nothing.

Ken Wood, by email

Top tip Ken – the unnamed supermarket wasn't by any chance Lidl was it? I know they often go in for super-cheap items that seem to have little to do with their 'normal' supermarket offerings. Ultrasounds cleaning tanks, angle grinders, garage hoists and other tools have all been regularly offered at amazingly low prices.

True, the quality is not always 'top drawer', but if you just need components or the one-off use of an item, they can be extraordinarily good value. See 'Special offers' at: **www.lidl.co.uk**

Thumbs up for Digital LC meter

Dear Editor
I have just completed the construction of the *Digital LC Meter* featured in the March 2010 edition of *EPE*.

I ordered most of the main parts for this project from Jaycar in Australia, which swiftly arrived. I then proceeded to follow the excellent construction information.

May I now tell your readers how pleased I am with the performance of this meter, which worked perfectly the first time I switched on the power. I have tested various mica capacitors on this meter, so I know it is giving very accurate capacitance readings. I wonder if any more of your readers have constructed this excellent project?

John Baldwin, by email

Thanks for the 'thumbs up' for both the project and the component supplier. I do occasionally worry that readers are put off a project because they need to order parts from Australia. Your experience echoes that of others – Jaycar are a reliable firm to deal with and it takes just a few extra days for their projects and components to reach us here in the UK

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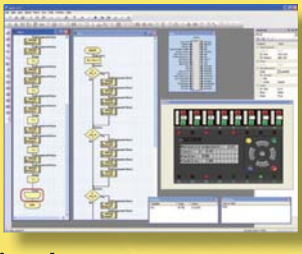

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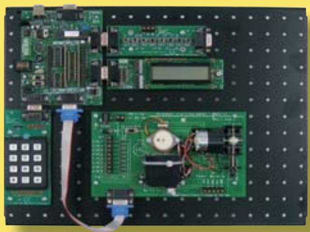

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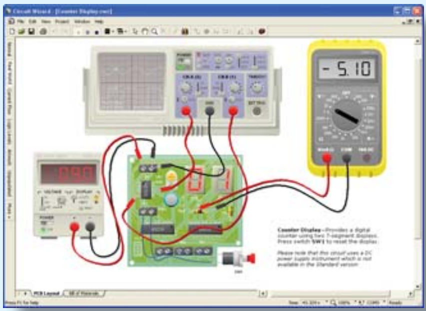

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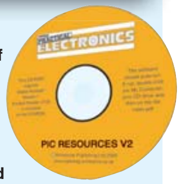

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Alan Winstanley

A near miss

ACCORDING to a recent Symantec Intelligence report, the UK is the most targeted geographical area for phishing attacks, overtaking even South Africa. One in 127 UK emails was flagged as a phishing attempt, ten times more than in the USA, and one hundred times more than in Japan. Spam levels, however, remain at about 78% of all email traffic.

Earlier this year, Microsoft partnered with various worldwide agencies to defeat one of the most notorious spamming networks, Rustock, which had one million infected PCs under its control in a 'botnet' that sent out billions of junk mails every day. You can read more of this type of Trojan threat, together with Microsoft's advice for protecting yourself, at **http://tinyurl.com/3vw6eye**

I receive tiresome phishing emails throughout the day, and needless to say they are immediately deleted, but some efforts at online robbery are so cleverly disguised that they almost fool even the author. Online crooks have become very sophisticated in their endeavours, and a clear trend is emerging of running highly targeted campaigns to defraud innocent victims without mercy.

The term 'spear phishing' refers to a cunningly focussed attempt to defraud victims by social engineering, aimed at a specific group rather than the public at large. Crooks might, for example, have gained the staff listing or member database of a corporation, or hacked into a social networking list. The crooks send recipients a phishing email that includes, for example, their full name or member ID, to give it more credibility. The recipient may be encouraged to 'log in' on a dubious link, which consequently plants a Trojan into their system, which might capture confidential bank logins or keystrokes.

Online vigilance

Vigilance online is more important than ever. A nasty example of social engineering fraud that I experienced first hand came in the form of an email from a close friend's Yahoo email address that I recognised instantly. The sender said that she had hopped over to Spain for a quick holiday, which is exactly the sort of thing that she does, but she had been robbed of her cash, wallet and phone at gunpoint. The plane was due to leave for the UK, the email claimed, but the hotel manager would not let them check out until the bill was paid. Could I help?

The mail was written in exactly her style, and it barely crossed my mind that the whole thing could be a hoax, and I treated this as an urgent plea for help from a good friend. Then I slapped my forehead: hang on a minute! I phoned her UK office number and she immediately answered (what a relief!). Someone had hacked her Yahoo email and sent out a fraudulent email through her address book, she explained.

I can honestly say that I was fooled initially, and indeed a day or two later I got another email from 'Spain' together with… a Western Union transfer request for £1,200. I also noted a Reply-To: email address was slightly different, so they had baited and switched me to another email account.

Going digital

In the past few months, I highlighted some of the trends in home and mobile networking, including the launch of new Google OS Chromebooks – these always-on netbook-style devices rely on finding an Internet connection so that they can access a number of services that are hosted in the 'cloud'. Chromebooks power up in a few seconds and Google claims they relieve the users of the need to constantly patch an operating system or guard their hardware against viruses. Even so, risks such as website cross-site script (XSS) vulnerabilities are now being identified, which are likely to make cloud-based working less than 100% secure.

Documents, mail, presentations, family photos, blogs or spreadsheets can all be hosted in the cloud for free and for many, Google's Gmail has become an indispensable tool. We don't seem to mind that our emails are 'read' by Google in search of money-spinning keywords – an email I just viewed in Gmail for a printing quotation is surrounded by Google Ads for banners, business cards and posters.

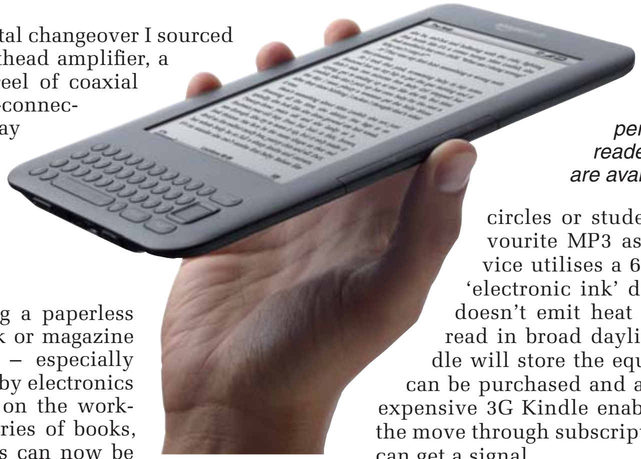
This Humax personal video recorder (PVR) has twin tuners and hard disk, and includes USB and ethernet ports for connecting to your router

Network technology is reaching into the home in other ways, as an exciting choice of hardware becomes available. Our enjoyment of digital TV can be enhanced with personal video recorders (PVRs) such as the remarkable range of satellite and terrestrial PVRs produced by Humax (**www.humaxdigital.com**) that use hard disks to record a TV programme or series automatically. Some models connect to the Internet via an ethernet port (eg, using Homegrid or Homeplug adaptors through the mains) or via a Humax USB WiFi dongle, enabling online services such as BBC iPlayer to be accessed.

They can also connect to a home network media drive to display family photos or video clips on a TV, turning your TV into a giant digital picture frame. Look for DLNA-compatible hardware – the logo of the Digital Living Network Alliance (**www.dlna.org**) which tries to ensure that all DLNA-compatible equipment will network together successfully, even when manufactured by different brands.

With swathes of the UK still awaiting the changeover to digital TV in 2011 and 2012, it is worth planning in advance and plenty of information is available online. *EPE* readers will be interested in the hardware changes needed, and it ultimately boils down to two choices: satellite TV through a dish (free or paid-for), or free terrestrial TV through an aerial. UK readers can check **www.freeview.co.uk** and **www.freesat.co.uk** for independent advice. Connection diagrams are available on the Digital TV Group website at **http://www.dtg.org.uk**.

Ready for my own digital changeover I sourced an excellent Vision masthead amplifier, a Humax digital PVR, a reel of coaxial cable and a bunch of F-connectors and couplers via eBay at an excellent price. As usual, plan ahead, shop around online and you can save yourself a fortune.



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Kindled spirits

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Perhaps the paperless society isn't quite here yet, but judging by the trends seen for instant music downloads, the attraction of ebook readers is broadening all the time.

You can write to the author at **alan@epemag.demon.co.uk** or log into our forum at **www.chatzones.co.uk**, or contact the editor directly with your comments for possible inclusion in *Readout*, at **editorial@wimborne.co.uk**.

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Electronics Teach-In 3

FREE CD-ROM

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered.

Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 different circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series.

The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages+CD-ROM **Order code ETI3** **£8.50**

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.

In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** **£5.99**

PROJECT CONSTRUCTION

IC 555 PROJECTS
E. A. Parr

Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note. No construction details are given.) A reference book of invaluable use to all those who have any interest in electronics, be they professional engineers or designers, students or hobbyists.

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HOW TO USE OSCILLOSCOPES AND OTHER TEST EQUIPMENT
R. A. Penfold

This book explains the basic function of an oscilloscope, gives a detailed explanation of all the standard controls, and provides advice on buying. A separate chapter deals with using an oscilloscope for fault finding on linear and logic circuits, plenty of example waveforms help to illustrate the control functions and the effects of various fault conditions. The function and use of various other pieces of test equipment are also covered, including signal generators, logic probes, logic pulsers and crystal calibrators.

104 pages **Order code BP267** **£5.49**

COMPUTING

COMPUTING FOR THE OLDER GENERATION
Jim Gatenby

Among the many practical and useful ideas for using your PC that are covered in this book are: Choosing, setting up and understanding your computer and its main components. Writing letters, leaflets, invitations, etc., and other word processing jobs. Keeping track of your finances using a spreadsheet. Recording details of holidays and other ideas using a database. Using the Internet to find useful information, and email to keep in touch with family and friends. Making 'back-up' copies of your work and checking for viruses. How to use Windows XP to help people with impaired vision, hearing or mobility.

308 pages **Order code BP601** **£8.99**

ELECTRONICS TEACH-IN 2 CD-ROM

CD-ROM

USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers.

An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Micrcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

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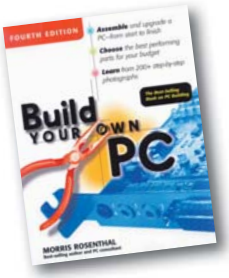


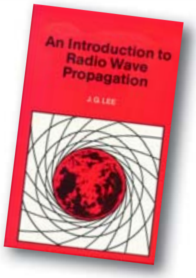
BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format **Order code MGH2** **£16.99**

RADIO



AN INTRODUCTION TO RADIO WAVE PROPOGATION
J.G. Lee

Radio wave propogation is one of the more important discoveries made in the early 20th century. Although technology lagged behind early experimenters pursued this newly discovered phenomenon eagerly for, in understanding the physics of propagation, they were discovering more about our Universe and its workings.

Radio wave propagation has its origins in the world of solar physics. The Sun's radiation provides the mechanism for the formation of the ionosphere. How the ionosphere is formed, and how it provides long-distance communication, is carefully explained. Non-ionospheric propagation, including 'moonbounce' or satellite communications, is covered as well.

This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find explanations of the propogation phenomena which both experience in their pursuit of communications enjoyment.

116 pages **Order code BP293** **£4.45**

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THEORY AND REFERENCE

BEBOP TO THE BOOLEAN BOOGIE
Second Edition
Clive (call me Max) Maxfield

This book gives the "big picture" of digital electronics. This in-depth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

470 pages **Order code BEB1** **£35.99**

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

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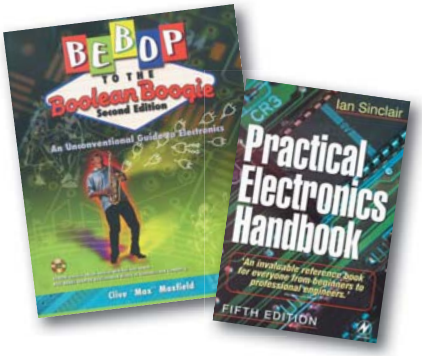

INTERFACING PIC MICROCONTROLLERS
Martin Bates

An essential guide to PIC interfacing techniques, using circuit simulation to aid learning.

Explore in detail microcontroller interfacing techniques using the popular PIC 16F877. Work through step-by-step examples interactively using circuit simulation software, supplied as assembly source code.

Interfacing PIC Microcontrollers provides a thorough introduction to interfacing techniques for students, hobbyists and engineers looking to take their knowledge of PIC application development to the next level. Each chapter ends with suggestions for further applications, based on the examples given, and numerous line drawings illustrate application of the hardware.

Step-by-step examples in assembly language are used to illustrate a comprehensive set of interfaces, and these can be run interactively on circuit simulation software, used to aid understanding without the need to build real hardware.

A companion website includes all examples in the text which cam be downloaded together with a free version of Proteus's ISIS Lite.

298 pages **Order code NE48** **£30.99**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** **£5.49**

OPERATIONAL AMPLIFIER USER'S HANDBOOK
R. A. Penfold

The first part of this book covers standard operational amplifier based "building blocks" (integrator, precision rectifier, function generator, amplifiers, etc), and considers the ways in which modern devices can be used to give superior performance in each one. The second part describes a number of practical circuits that exploit modern operational amplifiers, such as high slew-rate, ultra low noise, and low input offset devices. The projects include: Low noise tape preamplifier, low noise RIAA preamplifier, audio power amplifiers, d.c. power controllers, opto-isolator audio link, audio millivolt meter, temperature monitor, low distortion audio signalgenerator, simple video fader, and many more.

120 pages **Order code BP335** **£5.45**

PRACTICAL ELECTRONICS HANDBOOK – Fifth Edition. Ian Sinclair

Provides a practical and comprehensive collection of circuits, rules of thumb and design data for professional engineers, students and enthusaists, and therefore enough background to allow the understanding and development of a range of basic circuits.

Contents: Passive components, Active discrete components, Circuits, Linear I.C.s, Energy conversion components, Digital I.C.s, Microprocessors and microprocessor systems, Transferring digital data, Digital-analogue conversions, Computer aids in electronics, Hardware components and practical work, Micro-controllers and PLCs, Digital broadcasting, Electronic security.

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MUSIC, AUDIO AND VIDEO

QUICK GUIDE TO DIGITAL AUDIO RECORDING
Ian Waugh

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- Sound and digital audio essentials
- What to look for in a sound card
- What effects to use
- The art of mixing
- How to burn your music to CD
- How to post your songs on the Web

All modern music recordings use digital audio technology. Now everyone with a compouter can produce CD-quality recordings and this book shows you how. Written in a clear and straightforward style, it explains what digital audio recording is, how to use it, the equipment you need, what sort of software is available and how to achieve professional results.

Computer-based recording is the future of music and this book shows how you can join the revolution now.

208 pages **Order code PC121** **£7.95**

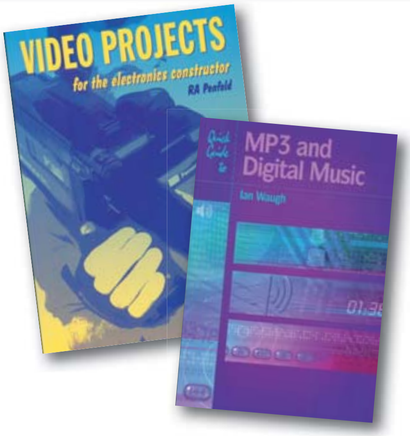
QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

60 pages **Order code PC119** **£7.45**



ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

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MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett

Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.

You'll learn about recording techniques, software and effects, mixing, mastering and CD production.

Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

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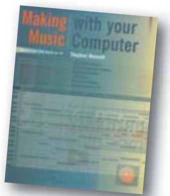

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FAULT FINDING, CIRCUITS AND DESIGN

STARTING ELECTRONICS
Third Edition
Keith brindley

BOOK + CD-ROM

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits. Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

288 pages | **Order code NE42** | **£15.99**

HOW ELECTRONIC THINGS WORK – AND WHAT TO DO WHEN THEY DON'T
Robert Goodman

You never again have to be flummoxed, flustered or taken for a ride by a piece of electronics equipment. With this fully illustrated, simple-to-use guide, you will get a grasp on the workings of the electronic world that surrounds you – and even learn to make your own repairs.

You don't need any technical experience. This book gives you: Clear explanations of how things work, written in everyday language. Easy-to-follow, illustrated instructions on using test equipment to diagnose problems. Guidelines to help you decide for or against professional repair. Tips on protecting your expensive equipment from lightning and other electrical damage, lubrication and maintenance suggestions.

Covers: colour TVs, VCRs, radios, PCs, CD players, printers, telephones, monitors, camcorders, satellite dishes, and much more!

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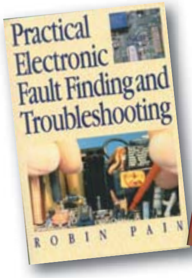
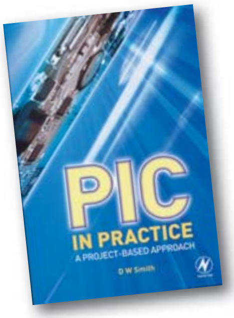


PIC IN PRACTICE (2nd Edition)
David W. Smith

A graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling hobbyists and students to develop their understanding at their own pace. The book can be used at a variety of levels.

Contents: Introduction to the PIC microcontroller; Programming the 16F84 microcontroller; Introductory projects; Headers, porting code – which micro?; Using inputs; Keypad scanning; Program examples; The 16C54 microcontroller; Alphanumeric displays; Analogue to digital conversion; Radio transmitters and receivers; EEPROM data memory; Interrupts; The 12 series 8-pin microcontroller; The 16F87X microcontroller; The 16F62X microcontroller; Projects; Instruction set, files and registers; Appendices; Index.



308 pages | **Order code NE39** | **£24.99**

PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain

To be a real fault finder, you must be able to get a feel for what is going on in the circuit you are examining. In this book Robin Pain explains the basic techniques needed to be a fault finder.

Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.

The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.

274 pages | **Order code NE22** | **£41.99**

A BEGINNERS GUIDE TO CMOS DIGITAL ICs
R. A. Penfold

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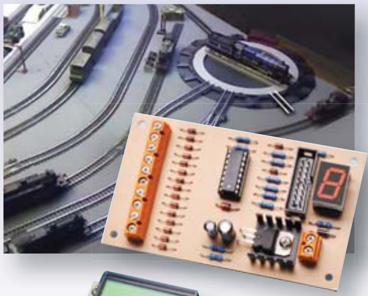

Digital Capacitor Leakage Meter
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One-of-nine switch indicator
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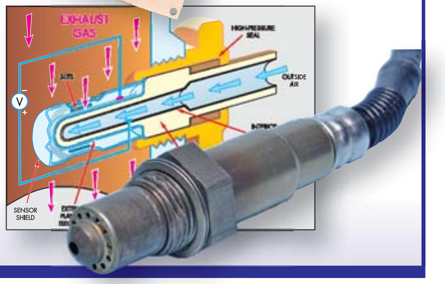
A high-quality stereo DAC for superb sound from your DVD player – Part 3
The final article in this series shows you how to assemble the various modules for the Stereo DAC into a low-profile steel case. We'll also tell you how to get the remote control working and how to customise the configuration.

Using a wideband O2 sensor in your car – Part 1
Following on from October's display project, this Wideband Controller is intended to be used with a Bosch LSU4.2 oxygen sensor to accurately measure air/fuel ratios. It can be used for precise engine tuning and can be a permanent installation in the car or a temporary connection to the tailpipe.



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